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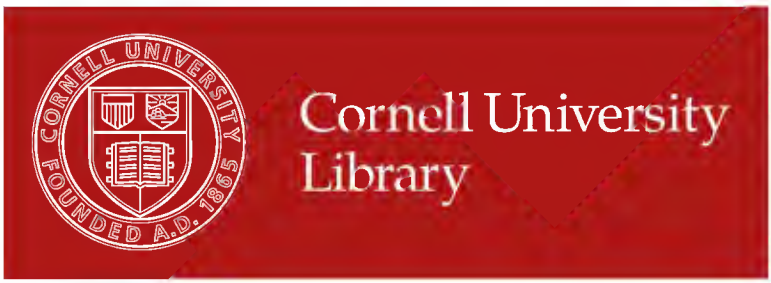

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY OF
ESKDALE, ROSEDALE, &c.

(EXPLANATION OF QUARTER-SHEET 96 N.E.)
(NEW SERIES, SHEET 43.)

BY

C. FOX-STRANGWAYS, F.G.S., C. REID, F.G.S.,
AND G. BARROW, F.G.S.

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1885.

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1885.

Price One Shilling and Sixpence.

NOTICE.

The following Memoir describes the geology of the highest and most picturesque part of the great tableland of the north-east of Yorkshire. The Map to which it refers shows that this region may be regarded as a vast model exemplifying, in a striking manner, the relations of topographical feature to the nature and disposition of the rocks underneath. The strata being nearly horizontal and little disturbed by dislocations, the valleys radiating from the tableland can be traced out as the results of erosion, with a precision and completeness unattainable in other districts of the country where the geological structure is less simple. Standing at the head of any one of these valleys, the observer has the whole sequence of rocks laid bare before him from the middle of the Lower Oolites down to the Lower Lias, and with his eye can follow the successive subdivisions of the Lias as their outcrops wind along the slopes. The absence of Drift over most of the country depicted on the Map is one of the most remarkable features of the geology. Boulder Clay, of the usual type, extents to a height of about 800 feet up the valleys that trench the northern front of the tableland, but is not met with in the interior, nor has any trace been found there of local glaciation. These uplands appear to have formed an insular space round which the ice-sheets swept but which remained unsubmerged. In the Drift edition of the Map the limits of the glaciated and non-glaciated tracts can best be seen.

The Lias and Lower and Middle Oolites are well represented in the District, and the present Memoir is mainly devoted to a description of these strata as developed within the area embraced by the Map.

ARCH. GEIKIE,
Director General.

Geological Survey Office,
January 28, 1885.

o 15617. Wt. 17758.

NOTICE.

The one-inch Map, of which the following pages are an explanation, is numbered 96 N.E. of the Geological Survey Map. In the New Series of the Ordnance Survey the Sheet is numbered 43. Two editions of the Ma pare published, one showing the Solid Geology only, the other showing the Drift. The price of each Map is three shillings.

The area was surveyed, under the superintendence of Mr. H. H. Howell, by Mr. C. Fox-Strangways (south and south-east part); Mr. Clement Reid (central area), and Mr. George Barrow (north and west). Each officer describes the area for which he is responsible, but Mr. Fox-Strangways has edited the whole.

The area is further illustrated by the following six-inch Maps of Yorkshire, viz., Sheets 43, 44, 45, 58, 59, 60, and by parts of Sheets 29, 30, 31, 73, 74, 75. These Maps are not published by the Geological Survey, but MS. Coloured Copies are deposited for public reference in the Survey Office.

Five sheets of Horizontal Sections, on a scale of six inches to one mile, traverse the district; these are—Sheets 131, 132, 134, 135, 137; they are published at five shillings each.

H. W. BRISTOW,
Senior Director.

Geological Survey Office,
28, Jermyn Street, London, S.W.
January 1885.

CONTENTS.

THE GEOLOGY OF

ESKDALE, ROSEDALE, &c.

CHAPTER I.

INTRODUCTION

The Quarter-Sheet 96 N.E., of which the following pages are an explanation, has an area of 216 square miles; it comprises the highest ground in North-east Yorkshire, and contains the finest dale and moorland scenery in that part of the county.

The map contains no towns, but there are several villages, more particularly along its southern edge, and in Esk Dale: the greater part of the area, however, being moorland, the population is mostly scattered along the sides of the great dales which have been brought into cultivation.

The principal villages in the south of the map are Lockton, Levisham, Newton, Lastingham, Spaunton, Hutton-le-Hole, and Gillamoor. Along Esk Dale there are Grosmont, Egton, Glaisdale, Lealholme Bridge, Danby, and Castleton: besides which may be mentioned Goathland, Rosedale, Chop Gate, and Ingleby Greenhow. Some of these—especially Rosedale, Grosmont, and Glaisdale—are of considerable importance from the iron industry which has been carried on at them.

The watershed dividing the drainage of the Derwent from that flowing north crosses the centre of the map and rises from an average height of about 900 feet in the east to 1,489 feet at Burton Head, the highest point in East Yorkshire. South of this line we have the great valleys of Bilsdale, Bransdale, Farndale, Rosedale, and Newton Dale, all tributary to the Derwent; and north of it there is the valley of the Esk with its tributaries flowing to the sea at Whitby, and the low-lying ground about Ingleby Greenhow in the north-west corner, which drains into the Tees.

The greater part of the surface is occupied by the Estuarine Series of the Lower Oolites, which in this district have a very coal-measure aspect, and have been extensively worked for the thin coals which they contain. These beds are cut through by the great valleys mentioned above, which expose the various divisions of the Lias. Along the southern part of the map is a narrow

strip of Middle Oolites, forming the northern edge and escarpment of the Tabular Hills, described in the Memoir on Quarter-Sheet 96 S.E.

Table of Formations.

The following are the geological formations which occur in the district:—

Post Tertiary	Recent and Post Glacial	Alluvium.
		Peat.
	Glacial	Boulder Clay and Gravel.
Tertiary?	Igneous.	Basalt (Whinstone).
Secondary	Middle Oolite.	Middle Calcareous Grit.
		Lower Limestone.
		Passage Beds.
		Lower Calcareous Grit.
		Oxford Clay.
		Kellaways Rock.
	Lower Oolite.	Cornbrash.
		Upper Estuarine Series with Moor Grit.
		Grey Limestone Series.
		Lower Estuarine Series with thin Coals and the "Eller Beck Bed."
		Dogger.
	Lias.	Upper Lias.
		Middle Lias.
		Lower Lias.

CHAPTER II.

LIAS.

Lower Lias.

The Lower Lias consists of grey, earthy, rather sandy shales, with tough ferruginous doggers and lines of decayed fossils. None of the dales except Bilsdale and the low ground in the north-west corner of the map are cut more than 160 feet into the Lower Lias, so no beds below the zone of *Ammonites capricornus* are exposed.

The most easterly exposure of the Lower Lias is in the bed of the Esk below the third railway bridge north-east of Grosmont Ironworks; the beds here consist of rather hard, sandy, grey, micaceous shales with rows of ferruginous nodules often remarkably spherical. These sometimes contain *Am. capricornus*, but fossils, as a rule, are not common. Only about 50 feet of Lower Lias is seen in this neighbourhood.

In Glaisdale there is so much Drift that it is impossible to say whether Lower Lias occurs. If it occurs, it is entirely hidden by the Boulder Clay, and as there is no means of measuring the depth of the Drift, no beds beneath the Middle Lias have here been mapped.

In Great Fryup the Lower Lias is not reached, but the adjoining dale of Little Fryup cuts about 25 feet into it. There is no good section, though the earthy shales can be seen in the stream below Crosley Side House.

Danby Dale being quite free from Drift, the grey, earthy shales can be examined at several points in the bed of the stream between Gate House and Honey Bee Nest. The sections are small and no fossils were observed. Not more than 30 feet of the Lower Lias has been cut through.

The sections in Westerdale are much better and a larger area of Lower Lias is exposed. Immediately west of the fault near Low Farm a low cliff overhanging the stream shows:*

	Ft.	In.
Shale with tough doggers - - - - -	4	0
Line of decayed fossils - - - - -	0	3
Shale with scattered fossils and tough pyritous doggers	5	0
Earthy shale with few fossils - - - -	9	0
Total - - - -	18	3

For a long distance the Lower Lias dips with the stream, so that, though it is exposed for fully three miles in the bottom of Westerdale, there is probably nowhere more than 40 or 50 feet of

* This and all succeeding sections are given in descending order.

the upper portion exposed. A furlong east of Hunter's Stile Bridge a scar on the south side of the stream shows:—

	Ft.	In.
Shale with doggers	20	0
Oolitic ironstone	0	6
Shale with doggers	6	0
Total	26	6

The top of this section is very near the base of the Middle Lias. The occurrence of oolitic ironstone is very unusual in the Lower Lias, and at first caused some doubt as to whether the beds might not belong to the Ironstone Series of the Middle Lias. However, earthy shales containing a seam of impure ironstone, with *Ammonites capricornus*, seen in the gill leading to Westerdale Hall, prove that these shales belong to the Lower Lias. The section is poor, but shows an irregular line of earthy ironstone full of fossils, including abundance of *Am. capricornus*. In the road and cliff between the village and the Esk there is:—

		Ft.	In.
Sandy Shale.	Flaggy sandstone, passing into Shale, rather sandy, with tough doggers	30	0
		5	0
Lower Lias.	Shale, with a few scattered tough, earthy doggers	35	0

Half a mile south-west of Benjy House the oolitic ironstone is again seen in the stream, and from the occurrence of slag heaps a few yards west, and also half a mile north, this ironstone would appear to have been one of the seams anciently worked. At a point a mile further south a change in the dip rapidly carries the beds beneath the stream, and though numerous exposures of the shale are found, there are no good continuous sections. In the eastern branch of Westerdale there is another small inlier.

In the north-west corner of the map the great plain is completely drift covered, and although a large area of the Lower Lias exists at the foot of the great Ingleby escarpment it is only in the Leven, between Kildale and Easby, that any clear sections are seen. This stream, in passing over the junction of the Middle and Lower Lias, just beyond the limit of the map, makes a small waterfall, one of the most picturesque in the district; below this, sections of grey, sandy, micaceous shale occur at intervals as far as Burrow Green's Wood. In Bilsdale the Lower Lias is first seen just south of The Holme, and from this point down the dale small exposures are numerous, especially in the neighbourhood of Chop Gate. Near here, in Raisdale Beck, just above its junction with this dale, is a line of small ironstone nodules containing the usual fossils, which are the lowest beds reached in the dale; in the bank above, shales with *Am. capricornus* are seen. Hollow Bottom Beck near Crookleth flows over these beds for a considerable distance, and the shales are also seen at intervals in the banks of the Seph. In Tripsdale, just below Hagg House, the junction of these beds with the Middle Lias is clearly seen, but further down the stream there are no more clear exposures.

Bransdale cuts about 60 or 70 feet into the Lower Lias, but though there are several small sections of earthy shale, no detailed measurements can be obtained.

Though Farndale shows far more of the Lower Lias than the other inliers, the undulating country these earthy shales form seldom shows sections of more than a few feet. The total thickness of Lower Lias here exposed must be fully 160 feet.

Middle Lias.

The Middle Lias of this district can be divided into two deposits of distinct lithological character: a lower "Sandy Series" and an upper or "Ironstone Series." Both, however, are very ferruginous, though workable ironstone only occurs in the higher division.

The "Sandy Series," forming the "Marlstone" of Phillips (though it is on a lower horizon than the Marlstone of the south of England), consists of sandy ferruginous shales passing into thin-bedded, flaggy sandstones. The beds are full of casts of fossils, especially *Cardium truncatum*, and measure about 70 feet in thickness.

The "Ironstone Series," so called from the occurrence of the well-known Cleveland Ironstone in it, consists of dark shale with seams of ironstone.

Sandy Series.—About Grosmont, on the south side of the Esk, several small sections are seen, from which the total thickness appears to be about 60 feet, but it is difficult to obtain many fossils from these exposures. On the north side of the river the Boulder Clay completely obscures these beds, but they were proved in a boring at the North Mine.

In Glaisdale though the Sandy Series undoubtedly occurs it is entirely hidden by Drift, and has therefore not been separated from the Ironstone Series.

Both Great and Little Fryup show several small sections of these shales, the best being in the gill near Fryup Hall, and in Slidney Dike, a quarter of a mile from Wood Head. In Little Fryup the shales are only seen in the beck south of Stone Beck Gate, and outcropping in the road a furlong east of the same place. None of these sections allow of detailed measurements.

The sections in Danby Dale are numerous though small. The best are in the immediate neighbourhood of the church, *Cardium truncatum* being found in abundance in the churchyard. Other exposures can be seen in the bridle road through Church Wood, and also in various parts of the gill below the wood. Road sections occur in Bur-tree Lane, near Gate House, and at Midge Holes, and there are also small exposures in the two gills north-east of Nook House.

In Westerdale there are probably better sections of the Sandy Series than in any other of the inliers, but nowhere can the beds

be measured. Commencing with the eastern branch of the dale, exposures of sandy shale can be examined a short distance south of Wyett Bridge, and also in the gill near Petch House. The higher part of the same gill shows thin cherty flags, probably belonging to the Sandy Series, but of a character unusual in the Lias. At the north end of Old Mill Wood there is a small section of flaggy sandstone, and similar beds re-appear in the gills east of Tower Bridge. Further south, at Cock Bannock and near Round Hill, sandy shales with cherty ironstone doggers are seen, probably forming the top of the Sandy Series.

Some of the best sections in Westerdale are seen in Bagdale Dike, near Westerdale Hall, where sandy shales and flaggy sandstone with *Cardium truncatum* are exposed. The same beds re-appear in Flats Gill, near the Grange. Though the shales are again seen in Stock Dale there is a good deal of disturbance in the whole of the western branch of Westerdale. The only other clear section occurs due east of Robin Leys House, where, close to the beck, a scar shows:—

	Ft.	In.
Flaggy sandstone.		
Shales	9	0
Line of micaceous ironstone doggers	0	9
Shale.		

the beds dipping a little W. of N. The sandy shales crop out in several other places in fields and road cuttings, but there are no clear exposures.

There is a small isolated patch of the Sandy Series outcropping on the hill side above Easby. The rocks here are obscured by the dense vegetation, but fragments of sandstone containing *Cardium truncatum* are found plentifully along the steep bank in Burrow Greens Wood. South of this great masses of gravel flank the main escarpment under Battersby Crags; the spur of rock in Coleson Banks being the first clear section of these beds, where a small opening, evidently near the base of the Middle Lias, shows thin flags with *Gryphæa cymbium*. Where clear of drift the Sandy Series forms a prominent terrace in the hill side, by which it may be traced round the great quadrangular escarpment; the detritus is, however, usually too thick to allow the beds *in situ* to show through, and it is only in large landslips that they are actually seen. The finest of these occurs at Blue Bell Trough, and gives the following section:—

Section of the Sandy Series at Blue Bell Trough, Burton Head.

	Ft.	In.
Calcareous and ferruginous sandstone with shaly partings, containing *Cardium truncatum*, &c. in great numbers	3	6
Hard, sandy shale and thin sandstone	5	0
Hard sandstone, ripple marked	4	0
Softer ferruginous sandy shale	7	0
Hard micaceous flaggy sandstone	3	6
Sandy shale	4	6

	Ft.	In.
Hard concretionary sandstone crowded with *Cardium truncatum*, *Gryphæa cymbium*, *Pecten sublævis*, *Pecten lunularis*, *Myacites*, sp., and occasionally *Ammonites margaritatus*	10	6
Shale	3	6
Sandstone (small speciems of *Cardium truncatum*)	1	0
Sandstone and shale bands alternating, with *Gryphæa* beds at base	25	0
Total	67	6

Passing round into Bilsdale, the west side of the high road shows a cutting in the upper sandstone beds of this series and exposures are numerous in the neighbourhood, almost every small stream flowing down the sides of the dale showing some part of the Sandy Series.

Just south of Chop Gate a bridle road goes up the hill on to the moor, where the rain has washed these beds bare so that they can be clearly examined though not measured. Good exposures also occur in Stingamire Gill on the west side of the dale, and in Kyloe Gill, just north of High Crosset, on the east; beyond which the Sandy Series dips beneath the bottom of the valley.

There are numerous small stream sections of the Sandy Series in Bransdale, especially in Beck Plantation, Gimmer Bank Wood, and at the southern extremity of the inlier. None, however, show anything of interest.

Farndale shows the largest inlier of the Sandy Series. The sections are of little importance, though sufficient to fix with considerable accuracy the boundary of this division.

The Sandy Series in Rosedale is only represented by two small inliers, exposing about 30 feet of the upper portion. The northern inlier extends along the River Seven from Dale Head Farm nearly to Storrey's House, the banks of the stream showing numerous small sections. A change in the dip carries the beds below the bottom of the valley for half a mile, but they reappear with the same character near Low House, and continue as far as Pry Hills, where a stronger southerly dip rapidly carries them beneath the Alluvium. The best sections are close to Rosedale Abbey, fossiliferous sandy shales appearing in the stream immediately below Bow Bridge, and also near the Foot Bridge leading to Hobb Farm.

Ironstone Series.—The upper portion of the Middle Lias, forming the "Ironstone Series" of Professor Phillips, is well represented in this map; though, from the thinness and general bad quality of the stone, mines are now only worked at Grosmont. The series reaches a thickness of from 60 to 80 feet, and consists of soft, dark, ferruginous shales, with thin bands of ironstone of variable thickness; the lower portion is hard and sandy, while the upper is grey, softer, and more earthy, and apparently forms a lithological passage into the Upper Lias. In the more westerly dales seams of oolitic ironstone occur, but, in the absence of mines, the positive correlation of the thin seams in these

valleys with the more important beds of Cleveland is scarcely safe. Probably there is a representative of the Main Seam in all these inliers, but in several of them none of the other seams could be recognised.

About Grosmont two of these, known as the Pecten and Avicula Seams, have been mined, and their position in the series may be seen from the following section measured in the banks of the Esk near Grosmont :—

Section of Ironstones near Grosmont.

	Ft.	In.
Indurated shale band, few ironstone nodules above	0	5
Shale with a few nodules and doggers—*Am. spinatus*, *Pecten æquivalvis*, &c.	5	0
Lenticular, sandy, ironstone band	0	6
Shale	3	4
Ironstone* with the large *Pecten æquivalvis*, *Belemnites*, &c.	1	0
Shale with large round doggers full of fossils	13	0
Ironstone 0 6 / Shale 1 3 / Ironstone 1 10 } Pecten Seam	3	7
Shale, hard, dark, and sandy	3	6
Two-Foot Seam.—Ironstone, hard, calcareous, and oolitic —*Am. clevelandicus*	0	10
Shale	25	0
Avicula Seam.—Ironstone	2	0
Shale, rather sandy	6	0
Band of hard, sandy shale	0	6
Hard shale, rather sandy	25	0
	89	8

The upper part of the above section was measured in the bed of the river just by the south end of the tunnel; the rest was measured just north of the mines.

There is a point of special interest in this section in the Murk Esk. The Pecten Seam does not contain the same fossils as the Main Seam of Cleveland, but it does contain the same as the shelly ironstone at the base of the seam at Eston. In fact, both in its fossils and mode of occurrence, the Pecten Bed shows itself clearly to be the same as the Eston shelly bed, and from this we infer that the Cleveland Main Seam is not the same as the Pecten Seam, but is above the latter. It has been stated, apparently without any good reason, that the Main Seam, which splits up into two as it passes eastward, is represented at Grosmont by the Pecten and Avicula Seams together.

In this case we should clearly expect that the two seams would pass continuously under the North Cleveland Hills and unite to the west. In reality, however, the Main Seam is represented at Grosmont by a band of impure ironstone only a foot in thickness, and it becomes at once evident that we must go a long way to the

* This is probably the representative of the Cleveland Main Seam.

west before it will have thickened sufficiently to be of any economic value.

The Pecten and Avicula Seams have been mined for some years past in the neighbourhood of Grosmont, but in consequence of the thinness and poor quality of the ore, several of these mines have been abandoned.

At the present mines the Pecten Seam is usually a shelly and somewhat shaly ironstone, gradually falling to pieces on exposure to the air. Its thickness is about 3 feet 6 inches, but only 2 feet 4 inches of this are workable ironstone, yielding an average of 26·5 per cent. of metallic iron.

This seam first appears at the junction of the Murk Esk and Lythe Beck, and is of the usual shelly character; it, however, soon dips beneath the stream under the railway bridge, and its outcrop being concealed by the buildings and rubbish heaps about the ironworks, is not again seen till a small gully is reached just above the next railway bridge to the north, where a similar section occurs. Further east the two seams were mined by the Whitby Stone Company; the Pecten Seam yielding about 2 feet 6 inches of ironstone.

The Avicula Seam rises from the river bed under the railway bridge north of the furnaces, but its exact thickness cannot be determined. The small *Ammonites clevelandicus* is abundant here, as is also *Pecten lunularis* and several other fossils, but they are rather decomposed. Sections of this seam may be seen in almost all the small gullies on the south side of the river, the usual thickness of the ironstone being about 3 feet 6 inches, but on the north side of the stream the Boulder Clay is so thick that no natural sections occur. At Grosmont Mines the usual thickness of ironstone is about 2 feet 6 inches, but in the mine on the opposite bank of that river it is 3 feet 6 inches thick. Both seams were proved in a shaft sunk about half a mile south of Grosmont, known as the Esk Valley Mine, where the two seams were proved at a depth of 64 and 70 yards respectively, the Pecten Seam being 3 feet thick and the Avicula Seam about 2 feet.

In Glaisdale the only section which can now be examined is in West Arnecliffe Wood. Here the beck has left the old valley, which is now filled with drift, and has cut a gorge through solid rock. About 10 chains east of Bank House Beck there is:—

	Ft.	In.
Grey shale with earth doggers containing *Ammonites annulatus*	10	0
I. Row of ferruginous limestone doggers, tough, fracture rather earthy, fossiliferous: *Belemnites*, &c.	0	4
II. Hard shale	4	0
III. Row of very irregular ferruginous limestone doggers, fossiliferous	0	6
IV. "Indurated shale" band	1	6
V. Hard shale	2	0
VI. Limestone, like I., but not so calcareous	0	8
VII. Shale with occasional *Belemnites*	1	4
VIII. Limestone, effervescing strongly, crowded with fossils often filled with zinc-blende	0	6

	Ft.	In.
IX. Shale	3	0
X. Large lenticular doggers 4′ or 5′ across and 10″ thick, no fossils observed (like VI.)	0	10
XI. Shale with occasional *Belemnites*	2	4
XII. Lenticular doggers rather closer together than X. The shale on the same horizon contains a large *Pecten* and other fossils	0	6
XIII. Shale	1	0
XIV. Ironstone, decomposed	0	4
XV. Ironstone, slightly oolitic, effervescing faintly	1	2
XVI. Ironstone, decomposed	0	1
XVII. Shale	2	0
XVIII. Ironstone, very fossiliferous and oolitic	1	7
XIX. Hard shale	0	4
XX. Row of large flat doggers, fine grained, not calcareous, fossils rare	0	6
XXI. Shale	1	6
Total	36	0

The ironstone XIV. to XVIII. is not worth working, being thin, though of fairly good quality. Mr. Parker states that analysis gives—

	Average, including Top.	Average, without Top.
Silica	10·27	8·76
Alumina	7·58	7·99
Protoxide of iron	33·99	35·35
Lime	10·63	10·58
Magnesia	4·11	4·32
Phosphoric acid	1·50	·93
Sulphur	·48	·48
Carbonic Acid Water, &c.	30·60	31·18
Protoxide of manganese	1·12	1·14
	100·28	100·73
Loss by calcination	26·83	27·25
Iron in dried sample	26·43	27·49
Iron in calcined sample	36·10	37·76

The following analysis (taken from Percy's Metallurgy, Iron and Steel, p. 223) may be useful for comparison :—

	Avicula Seam.	Pecten Seam.
Protoxide of iron	33·86	34·98
,, manganese	0·50	0·48
Alumina	3·92	3·20
Lime	11·90	11·96
Magnesia	4·52	4·51
Carbonic acid	28·00	29·20
Phosphoric acid	0·48	1·30
Water	3·65	3·30
Ignited insoluble residue	13·22	10·04
	99·36	98·97

The insoluble residue gave 9·42 of silica in the case of the Avicula Seam and 8·00 in the case of the Pecten, the former seam yielding 25·80 per cent. of metallic iron, the latter 27·21.

The seams in the Esk Valley mines gave the following analyses:—*

	Pecten Seam.	Avicula Seam.
Silica	9·75	14·52
Alumina	8·36	12·65
Protoxide of iron	32·74	32·87
Lime	10·97	7·82
Manganese	4·33	4·81
Phosphoric acid	1·19	·55
Sulphur	·30	·40
Carbonic Acid Water	31·23	27·05
	99·87	100·67
Loss by calcination	27·60	23·40
Iron in dry sample	25·46	25·55
,, calcined ,,	33·16	33·35

The following section of the abandoned pit at Glaisdale has been communicated by Mr. Bell of Swainby Mine:

		Ft.	In.
[Boulder Clay]	Clay	53	0
[Alum Shale]	Shale and cement doggers	67	0
[Base of Alum Shale and Jet Rock]	Jet rock	58	0
[Grey Shale]	Dogger	0	6
	Grey shale	5	0
	Dogger	0	6
	Grey shale	14	0
	Dogger	0	6
	Grey shale	3	0
	Dogger	0	6
[Ironstone Series.]	Hard shale ["indurated shale"]	1	6
	Pure shale	2	0
	Dogger	0	4
	Shale	1	8
	Small seam of stone with *Pecten*	0	6
	Shale	2	0
	Nodules	0	8
	Shale	4	0
	Nodules	0	6
	Pecten Seam 6 ft. 7 ins. — Ironstone	0	6
	Pecten Seam 6 ft. 7 ins. — Shale	0	8
	Pecten Seam 6 ft. 7 ins. — Ironstone	1	0
	Pecten Seam 6 ft. 7 ins. — Ironstone, mixed	0	9
	Pecten Seam 6 ft. 7 ins. — Shale	2	6
	Pecten Seam 6 ft. 7 ins. — Ironstone	1	2
	Shale	6	0
	Hard shale, slaty and gritty	6	0
	Shale	15	6
	Bottom Band 5 ft. — Ironstone	0	4
	Bottom Band 5 ft. — Shale	0	8
	Bottom Band 5 ft. — Ironstone	1	6
	Bottom Band 5 ft. — Shale	1	6
	Bottom Band 5 ft. — Ironstone	1	0
	Total	254	3

* From information supplied by Mr. Parker of Glaisdale.

Mr. Parker gives the Pecten Band in this mine as :—

	Ft.	In.
Ironstone	0	5 to 6
Shale (often wanting)	0	1 to 3
Ironstone	1	4
Black Ironstone Band	0	5
Shale	2	6
Ironstone	1	4

Some of the stone may still be seen near the furnaces, but the quality is so poor that it is surprising that it should ever have been worked. Analyses of the upper or so-called "Pecten" Seam by Messrs. Wallace, Tatlock, and Clark give an average of:—

Protoxide of iron	25·17
Peroxide of iron	2·58
Bisulphide of iron	1·62
Oxide of manganese	·46
Lime	3·27
Magnesia	2·30
Alumina	5·54
Silica	32·71
Phosphoric acid	1·80
Coaly matter	1·33
Carbonic acid	20·80
Water, extraneous	1·27
Water, combined	·72
Total	99·57

Iron as protoxide	19·55
—— peroxide	1·80
—— bisulphide	1·75
Sulphur	·86
Loss by calcination	20·98
Iron in calcined stone	28·15

The rest of the Ironstone Series in Glaisdale is hidden by Drift, with the exception of two small exposures where gills cross the road on each side of Hob Garth.

There are no good sections of this series in Fryup Dale, but a seam of oolitic ironstone can be traced through great part of Little Fryup. Where it crosses High Lane there is :—

	Feet.
Shale.	
Ironstone, fossiliferous, oolitic	about 1
Hard shale with lines of very tough unfossiliferous doggers	about 8
Ironstone, fossiliferous.	
Sandy shale.	

The seam, though only a few inches thick, appears to have been worked in former days, as there are several slag-heaps in different parts of the dale, and remains of the old furnaces have been found in Fairy Cross Plain. A thicker seam can be traced for a few yards in Rabbit Slack at the head of Great Fryup. The section is :—

	Ft.	In.
Grey shale.		
Shale with small doggers	8	0
Large lenticular IRONSTONE doggers	0	6
Shale	2	6
IRONSTONE, fossiliferous	1	7
Shale with flat pyritous doggers.		

This probably represents the Main Seam, but the one in Little Fryup appears to be on a lower horizon and cannot satisfactorily be correlated with any of the named seams.

In Danby Dale the thin ironstone reappears near Lumley House, at Nook House, and at Stormy Hall, though it cannot be measured at any of these localities. There are good sections of the accompanying shale near Smallwoods House, and at Mill Scroggs at the lower end of the dale.

The only clear section of the Ironstone Series in the eastern branch of Westerdale is to be seen in the gill immediately south of Swarthy Hill :—

	Ft.	In.
Shale	1	0
IRONSTONE doggers	2	3
Shale	0	3
IRONSTONE doggers	0	3
Shale	0	9
IRONSTONE, oolitic, fossiliferous	0	9
Shale and lines of tough doggers	8	0
Total	13	0

In the western branch of the dale the Main Seam is well shown in a trial hole a quarter of a mile north-east of Low Farm. Though rather obscured, the sections seems to be :—

	Ft.	In.
Very ferruginous shale and shaly IRONSTONE	5	0
Shale	1	0
IRONSTONE, oolitic, fossiliferous	2	2
Hard shale	2	0
Total	10	2

On the opposite side of the beck, immediately east of the fault, there is a good section of the beds beneath the ironstone :—

	Ft.	In.
Soft grey shale	4	0
Hard ferruginous shale with IRONSTONE doggers and *Pecten*	1	4
Ironstone shale	0	8
Line of doggers	0	3
Ironstone shale	4	0
——— ? (hidden) about	10	0
Ironstone shale	4	0
IRONSTONE, with fossils	0	3
Ironstone shale	7	0
IRONSTONE, fossiliferous, with pyrites and *Avicula* ?	0	8
Ironstone shale	4	0
Total	36	2

The plateau on which Westerdale Church stands is formed by the ironstone, here about a foot thick, and the pits so numerous in the neighbourhood mark the position of old workings. Ironstone, probably the same seam, can be traced for about half a mile near Stockdale House ploughed up in the fields. Near Waites Moor a change in the dip carries the Ironstone Series beneath the stream, but a small anticlinal at Esklets again brings up a few feet of these beds.

The Ironstone Series in Basedale is divided into two inliers, neither of large extent. The northerly one, on which Basedale Abbey is situated, shows a 4-inch seam of oolitic ironstone with *Belemnites* and a large *Pecten*, in the beck a furlong south of the Abbey. In the middle of the southern inlier there is a good section near the stream :—

Section in Basedale.

	Ft.	In.
Jet rock.		
Grey shale, very like ironstone shale	25	0
Line of small doggers with *Ammonites annulatus*.		
Shale	3	0
Doggers in harder shale ("indurated shale band")	0	8
Ironstone shale	11	0
Shale with lines of scattered septaria	3	0
Ironstone shale with a few scattered septaria	5	0
Total	47	8

About Kildale the Ironstone Series is mostly obscured by gravel and drift, but close by the Leven near the old mines the following section was exposed :—

*Section near Kildale.**

	Ft.	In.		Ft.	In.
Ironstone,	2	5			
Shale,	1	4	Main Seam	5	4
Ironstone,	1	7			
Shale with streaky ferruginous markings				3	8
Pecten Seam 2 ft. 6 in. — Ironstone, *Am. spinatus*; *Pecten æquivalvis*, &c.				0	11
Pecten Seam 2 ft. 6 in. — Shale parting				0	2
Pecten Seam 2 ft. 6 in. — Ironstone with nests of *Avicula*				0	2
Pecten Seam 2 ft. 6 in. — Shale parting				0	3
Pecten Seam 2 ft. 6 in. — Ironstone				0	6
Pecten Seam 2 ft. 6 in. — Shale parting				0	3
Pecten Seam 2 ft. 6 in. — Ironstone				0	3
Shale ferruginous and shelly				2	2
Oolitic ironstone, Two-Foot Seam				2	5

Along the Cleveland escarpment the covering of gravel and detritus conceals the outcrop of the Ironstone Series for some distance, and the only reliable information is to be gained from the Ingleby Mines, at which the following section was made :—

* This section is a few hundred yards north of the area included in the map.

	Ft.	In.
Shale with rows of ironstone nodules.		
Dogger band	0	3
Main Seam { Hard, grey IRONSTONE	2	0
Main Seam { Shale parting	1	4
4 ft. 10 in. { Hard, grey IRONSTONE	1	6
Shale parting	0	4
Pecten Seam, shaly IRONSTONE	1	8
Shale	2	9
Two-Foot Seam, IRONSTONE	2	0

There is no doubt that this last seam of ironstone is the Two-Foot Seam, as it contains *Avicula cygnipes*, small *Pecten*, *Cardium truncatum*, *Am. clevelandicus*, &c., while *Am. spinatus* and *Pecten æquivalvis* are absent. On the face of the escarpment the great landslip at Blue Bell Trough exposes the following section :—

	Ft.	In.
Ferruginous shale, resting on hard shale band	3	0
Impure oolitic IRONSTONE	1	3
Ferruginous shale	3	0
Shale with dogger bands	4	0
IRONSTONE, very hard	1	6
Laminated shale	6	0
Shale, darker and softer	12	0
IRONSTONE, with shale parting	0	9
Ferruginous shale	3	3
Thin, sandy IRONSTONE, *Cardium*, *Pecten*, &c.	0	3
Shale, ferruginous, sandy towards base	30	0
Total	65	2

From this section the Main Seam is evidently split up into two widely separate blocks; the Avicula or lowest Seam is perhaps in the upper part of the last 30 feet of shale, but covered by rubbish. Just before entering Bilsdale, ferruginous shales are seen close against the boundary wall at the head of the dale, and the first seam of ironstone is seen about a hundred yards to the south-west. The outcrop of the Main Seam continues clear for about three-quarters of a mile as far as the hamlet of Urra, and sections may be seen in both branches of the stream that flows down past the Holme, that at Cast Hills being as follows :—

Section of the Ironstone Series at Cast Hills.

	Ft.	In.
IRONSTONE	0	3
Shale	1	6
IRONSTONE	0	4
Shale	0	3
IRONSTONE* (probably Two-Foot Seam) with *Pecten liassicus*, *P. lunularis*, *P. sublævis*, *Cardium truncatum*, *Avicula cygnipes*, *A. novemcostæ*, *Myacites* sp. and *Belemnites* sp. abundant	1	6
Shale	14	0
IRONSTONE (probably Avicula Seam)	2	0

* From the fossils and the general character of the beds there can be little doubt that this is the Two-Foot Seam. The Main Seam was met with in a trial hole above; but this has fallen in, so that no details could be ascertained.

Above Mount House, and again in the village of Urra, portions of the Ironstone Series are exposed, but south of this the downwash obscures the strata for the distance of more than a mile.

On the west side of Bilsdale there is an exposure above the roadside at the foot of Hasty Bank, where a level has been made, but has since fallen in.

Close by the south end of Vittoria Plantation near the edge of the map in a small gill the following section occurs, but it is not clear to what seams the several ironstones correspond:—

	Ft.	In.
Shale with ironstone streaks	2	0
Mixed shale and IRONSTONE	1	10
Shale	2	0
IRONSTONE	0	2
Shale	1	8
IRONSTONE	0	4
Ferruginous shale	0	6
IRONSTONE	1	0

Above Broad Fields the Main Seam has a clear outcrop and makes a small well-defined terrace for a distance of about half a mile, occurring again in a similar position above Bank House.

The roads going up on to the moor above Breck House and Orterley both expose the ironstone, but its outcrop further south is obscured for a great distance, and it is not until we reach Stingamire Gill that any clear section is seen. Here a trial has been made in which three seams of ironstone may be made out; the lowest being of the best quality and about 1 ft. 6 ins. thick.

In Fangdale Beck the greater part of the Ironstone Series is exposed, and a trial hole, partly fallen in, gives the following section of the Main Seam:—

	Ft.	In.
IRONSTONE	1	0
Shale	3	0
IRONSTONE	1	0

The beds descend rapidly from this point, and one of the ironstone seams outcrops at the first sharp bend of the river north of Spout House, while at the next bend below ferruginous shale, evidently near the top of the series, is seen.

On the east side of the dale the Main Seam is exposed in a small gill opposite Chop Gate and the Avicula Seam is seen below William Beck. South of this there are exposures of ironstone at Ellermire, Cam House, and Oak House, and passing up Tripsdale the Avicula Seam, which is 2 feet thick, crosses the stream about half a mile above Hagg House, where the beds above are seen in a scar, but the bank was too perpendicular to measure the details.

In Tarn Hole Beck the following section was seen:—

	Ft.	In.
Ferruginous shale	5	0
Ironstone	0	5
Shale	2	0
Ironstone (Two-Foot Seam)	1	3
Shale	3	6
Sandy band	0	4
Shale	4	0
Ironstone	0	4
Micaceous sandstone	2	0
Shale	12	0
Ironstone (Avicula Seam)	1	9
Shale	5	0

It is noticeable here that the shales between the Two-Foot and Avicula Seams are decidedly more sandy, a feature that becomes more pronounced as we proceed in a south and west direction. The Main Seam is not exposed in this section. Further south the principal exposures of the Ironstone Series are in the roads by Appletree Hurst and Low Crosset, while in Crosset Plantation there are a number of old workings, but they are so ancient that no record of them is known in the dale.

The only exposure in Bransdale is in a trial hole near the northern end of Gimmer Bank Wood, where 16 inches of poor ironstone was found. Similar ironstone can be seen in the road above Mason House. In both cases it may represent the Main Seam.

A seam of oolitic ironstone measuring 10 or 11 inches can be recognised in various parts of the northern half of Farndale, but there are no continuous sections of the associated shales and no means of correlating the seam with those found in other dales.

In Rosedale a section in the stream near Dale Head shows:—

	Ft.	In.
Ironstone shale and doggers	8	0
Ironstone, fossiliferous	1	2
Ironstone shale and doggers	5	0
Total	14	2

A 6-inch seam of oolitic ironstone, possibly representing the thicker seam of the above section, can be examined in the beck near High House; it is also found near Bell End Houses, and can be traced for a short distance near Abbey Heads.

Upper Lias.

This division of the Lias consists of dark shales, mostly finely laminated and pyritous, which may be further subdivided into three parts, each of which corresponds to a well-marked palæontological zone, the Alum Shale or zone of *Am. communis*, the Jet Rock or zone of *Am. serpentinus*, and the Grey Shale or zone of *Am. annulatus*.

The Grey Shale.—The lowest of these, the Grey Shale, is a fine grey shale not so well laminated as the beds above. Being very soft it rarely forms vertical cliffs, consequently, though continuous and having a uniform thickness of about 30 feet throughout the whole area, the beds can seldom be measured or recognised by their fossils.

About Grosmont these shales, which have the same appearance as on the coast, are seen near the junction of the Esk and Murk Esk, and in the railway cutting just south of the tunnel.

Further west a section can be seen in West Arnecliffe Wood showing 10 feet of soft grey shale with earthy doggers containing the characteristic *Ammonites annulatus.*

In Fryup, Danby Dale, and Westerdale there are no clear sections of this horizon. In Basedale *Am. annulatus* is again found at two points; on the north side of the gill near Basedale Abbey, and again about half a mile further south, but only in the latter case is there a good exposure.

In the Leven valley, the lower part of the Upper Lias is completely hidden by Glacial deposits, but in the great Ingleby escarpment, although the downwash completely conceals the outcrop, the different beds may be made out from the line of jet holes which have been made along the bank.

In Blue Bell Trough, the great scar immediately under Burton Head, the Grey Shale is seen, and in Bilsdale, down both sides of the valley an almost continuous line of jet pits marks the horizon, but the only clear exposure is in Tripsdale, some distance above Hagg House.

In Bransdale and Farndale the features are sufficient to allow of the bed being traced all round the Dale, though there are no exposures. The same is the case in Rosedale, except where landslips obscure the geology and prevent the lines being continued.

The Jet Rock.—The Grey Shales are succeeded by about 25 feet of laminated shales, splitting up into thin plates and having a strong bituminous odour; these constitute the Jet Rock, throughout which pyrites occurs dispersed and in nodules, the latter being often formed round fossils, of which the chief are *Inoceramus dubius, Ammonites gracilis,* and several species of Ammonites of the *Am. serpentinus* type.

The outcrop of the Jet Rock on account of its having been extensively mined, is far better marked than that of the Grey Shale. The shale heaps from these workings show very clearly two points; first, that the rock is more fossiliferous in the eastern area, as about Grosmont; secondly, that it is more bituminous in the west about Ingleby, where, from inquiries, it appears that jet has been met with more abundantly, and the workings are so numerous that its outcrop can be followed without difficulty.

The Jet Rock is seen in the Murk Esk about Grosmont, and for a few yards in the bed of the beck in Egton Grange dipping with the stream. A section at the northern end of Park Hole Wood shows:—

		Feet.
Alum Shale.	Shale with yellow edges - - about	40
	Shale with a few lines of doggers, the upper ones cement stones, the lower more pyritous - -	18
Jet Rock.	Harder shale and small very tough pyritous doggers with *Inoceramus dubius*. One dogger was formed round a bone to which a number of *A. gracilis?* adhered - - - - - -	2
	Total - -	60

In West Arnecliffe Woods, the shales with *Am. gracilis* are again seen, but in the greater part of Glaisdale the Jet Rock is hidden by Boulder Clay, and it has only been mapped for a short distance near Hob Garth.

Jet Rock has been mined at Round Hill in Fryup, near Smallwoods House in Danby Dale, and very extensively over the greater part of Westerdale and Basedale. In fact, in Westerdale and Basedale, the outcrop can be accurately traced for long distances by the old workings.

Along the west of the map, the only good sections are at Blue Bell Trough, and in Tripsdale, just north of the section of the Grey Shale mentioned above.

In Bransdale, Farndale, and Rosedale, the workings have also been very extensive, and allow the bed to be traced almost continuously. As none of these dales show any marked variation from the usual character or thickness of the Jet Rock, there is no need of local descriptions, especially as none of the exposures show a continuous measurable section from the Alum Shale to the Grey Shale.

The Alum Shale.—The next division, the Alum Shale, is also very uniform over this area, except that it becomes less fossiliferous in the west and the abundant *Leda ovum* of the coast disappears, or at least becomes very rare west of Glaisdale, and the shale in which it occurs alters slightly in character, becoming rather harder. There is a gradual passage downwards into the Jet Rock, the true Alum Shale becoming harder, more platy and bituminous, and in the lower part containing large pyritous doggers with *Ammonites serpentinus*, very like those of the Jet Rock. The total thickness appears to be about 170 feet, but it is decidedly thinner to the west than about Grosmont.

The upper part of the Alum Shale is frequently exposed by small landslips. Good sections may be seen near Beck Hole, but its outcrop on the west side of the Murk Esk is completely concealed by drift and detritus. Some of the best sections, however, can be examined in the scars of the Esk and Glaisdale Beck, between Egton Bridge and West Arnecliffe. Near Egton the lower beds are well seen immediately above the stream, resting on the top of the Jet Rock. At Snowdon Nab the soft, yellow-edged Alum Shale with *Leda ovum* forms a small scar, but as these soft beds generally form a smooth slope there are no other good sections in Glaisdale.

The only satisfactory exposure in Fryup Dale is at the head of Great Fryup, where there are many large scars, kept nearly vertical by the rapid denudation. In Danby Dale, Westerdale, and Basedale the constant small landslips much obscure the Upper Lias, and though plenty of small exposures of the Alum Shale occur they are of little importance. In the bed of the Leven near its source, below Warren Moor, are two small exposures of Alum Shale, while in the great escarpment further west almost every small gill and scar exposes the upper portion of these beds as they sweep round this great cliff. The landslips at Rud Scar and Blue Bell Trough have caused fine exposures in which the paucity of fossils is remarkable when we compare these beds with the same strata about Grosmont and Whitby. On the east side of Bilsdale the top of the Lias is fairly well fixed by the line of sandstone above; but the shale itself, which sometimes contains *Ammonites communis*, although fossils as a rule are rare, is only occasionally seen in roads where it has been exposed by denudation.

In the upper part of Tripsdale the stream flows through a small gorge giving an almost complete section of the Upper Lias, which shows that the character of the Alum Shale is the same as it is further east, and the fossils, although of far less frequent occurrence occupy the same horizons; *Inoceramus dubius*, marking the lower beds, while *Ammonites communis*, *Am. bifrons*, and *Leda ovum* still characterise the upper portion. The junction of the Lias and the Oolite is well seen in Tarn Hole Beck to the south-east, but the intervening outcrop between the two streams is much obscured by landslips and vegetation.

On the west side of Bilsdale, where the junction of the Lias and the Oolite is generally clearer than on the east, there are several good exposures, namely, in Stingamire Gill and Fangdale Beck and along the face of the escarpment between.

Numerous small landslips cause much obscurity in Bransdale, Farndale, and Rosedale, so that though sections are abundant no detailed measurements can be obtained. There is, however, a very good exposure of the middle portion of the Alum Shale in Cat Nab Scar, at the head of Rosedale.

CHAPTER III.

LOWER OOLITE.

The Dogger.—Owing to the extreme variability of its lithological character it is very difficult to give a general description of the Dogger. It changes from a sandstone to a limestone or a valuable ironstone, and from a fine-grained shaly bed to a nodular calcareous oolitic rock with little bedding. In some places it seems to form a passage bed between the Lias and the Lower Oolites, in others it rests on a distinctly eroded surface of the shales, while here and there it is itself cut out entirely by the Estuarine Sandstones which rest immediately on the Alum Shale.

Immediately above the ironworks at Grosmont trial holes have been made in the Dogger, but owing to its sudden variations in character it was found to be of no value as iron ore. In one of these drifts, by the road side on the east, the bed is 4 feet thick and contained 24 per cent. of iron. The outcrop is remarkably clear about here and a drift in the banks of Lythe Beck shows 12 feet of highly fissile and ferruginous sandstone with many carbonaceous fragments, but apparently no marine fossils. South of this it passes through Crag Cliff Wood to the Whin Dyke, where it is seen calcined for a few feet. In the little stream close by it consists of soft brown sandstone at the base with 10 feet of more calcareous beds above, the usual band of rolled nodules being absent. It continues south through Blue Ber Wood as a calcareous sandstone, and then gradually becoming more ferruginous, passes into a concretionary ironstone, this character being well seen in a road above the smithy at Beck Hole, where the nodules with a few badly preserved fossils occur at the base. At Hollins Wood the Dogger descends into the bed of the river, making an exceptionally fine outcrop; it is here about 15 feet thick and consists of a bluish, coarse-grained, impure ironstone, the grains being so large as to be almost pisolitic. A trial hole was made close by and the upper part of the bed analysed, which was found to contain about 36·7 per cent. of iron, while another analysis from the same part of the seam, about 100 yards off, yielded only 19·32 per cent. of iron. A little north of this some ironworks were erected to smelt the stone obtained from this bed, but they have been long since disused.

On the west side of the Murk Esk, owing to landslips, the outcrop is more obscure, but its general course is quite clear from the numerous drifts into it. At Cat Scar, to the north of Grosmont, the Dogger, which is about 20 feet thick, is essentially a ferruginous sandstone, very flaggy and the lower part of the bed

containing 23 per cent. of iron. At Cote Banks it is similar in character but thinner.

The following analyses of the Dogger about Grosmont may be useful:— *

Protoxide of iron	32·78	23·20	40·77
„ manganese	0·45	0·50	0·48
Alumina	1·18	2·10	1·52
Lime	6·44	11·80	4·08
Magnesia	4·52	3·96	5·34
Carbonic acid	26·13	24·40	31·80
Phosphoric acid	0·48	0·30	0·06
Water	2·80	3·20	2·70
Ignited insoluble residue	24·10	30·96	12·36
Silica in insoluble residue	18·12	23·10	8·80
Yielding metallic iron	25·50	17·34	31·71

At Egton, there is a small section of the Dogger in each of the gills leading to Egton Bridge, but for some distance both east and west of this point it is entirely hidden by drift. At the western corner of Limber Hill Wood it reappears as a fine-grained ferruginous rock full of variously coloured specks, and containing a few fossils. On the south side of the Esk, opposite Egton, a section in Blue Beck shows:—

	Feet.
Earthy oolitic ironstone	12
Ferruginous shale	2
Alum shale.	

Similar beds are again seen in the road cutting above Scalby Hill. In Egton Grange there are no sections, the beds being entirely hidden by Boulder Clay.

In Glaisdale the Dogger, though scarcely more than a ferruginous sandstone, has been worked for ironstone and the trial holes and natural scars yield abundance of sections. On the north side of the dale the Dogger rises from beneath the Alluvium close to the Iron Works. The high dip, about 9°, carries it above the houses at Under Hill,† so that the trial drift there is about 100 feet above the stream. The section shows:—

		Ft.	In.
	Estuarine shales and sandstones, with ferns.		
Dogger	Irony shale	1	0
	Ironstone, rubbly and weathering into spheroids	2	6
	Ferruginous dogger with iron partings	7	0
	Nodular base	1	0
	Blue shale.		
	Total	11	6

* Dr. Percy's Metallurgy, Iron and Steel, page 223.

† *Red House* on the One-inch Map.

The stone is too poor for profitable working.

Westward the Dogger rises steadily, and a series of drifts at and near Post Gate Hill show similar ferruginous beds with a total thickness of about 12 feet. The spoil-heaps yield a greater abundance of fossils than in any other part of this district, but they are generally in the state of casts. Above Apple Garth Hall the Dogger becomes more flaggy, and further west, at the Sandstone Quarry, near High Hardhill, it has lost all claim to be called an ironstone, as it consists of sandy micaceous shale or sandstone. Southward the bed thickens till at the south-west corner of the dale it measures 16 feet, the upper portion being flaggy. Returning by the south side of the dale the Dogger again becomes ferruginous and fossiliferous, so that on the east side of Winter Gill it has again been tried for ironstone. A section in an open quarry half a mile north-east of Gill Beck shows:—

		Ft.	In.
	Flaggy estuarine sandstone and shales	10	0
Dogger	Flaggy grey ironstone, with comminuted shells?	2	0
	Earthy ironstone with iron partings	3	0
	Nodular rubbly band, the nodules made up of oolitic ironstone (perhaps conglomeratic)	1	3
	Earthy ironstone as above, *Terebratula trilineata*, &c.—fossils principally near the base	9	6
	Soft blue shale.		
	Total	25	9

In Bank House Beck the section is:—

	Feet.
Sandstone and shale	4
Oolitic earthy Dogger	6
Shale.	

East of this point, though there are no clear sections, the Dogger appears to be very thin.

Between Glaisdale End and Lealholm Bridge the dip carries the Dogger beneath the river bed. In Crankly Gill—the gorge of the Esk above the latter place—it reappears, and at the most southern part of the bend of the stream the section is:—

		Feet.
Dogger	Ironstone	4
	Nodular band	1
	Fossiliferous Dogger	10
	Alum shale.	
	Total	15

North of the Esk the Dogger has been tried for ironstone at Oakley Side, and on the south side it has also been tried at Finkel House in Great Fryup, where it has a thickness of 25 feet. Between Finkel House and Glaisdale Wood Head it can easily be

traced, though measurable sections are rare. A very good exposure in Yew Grain Scar at the head of Great Fryup shows :—

	Feet.
Ferruginous sandstone, shaly and fossiliferous at the base Alum shale.	32

At Slidney Piece another section gives :—

	Feet.
Estuarine shale	15
Ferruginous sandstone, slightly false-bedded	10
Shale	7
Dogger with fossils	20
Total	52

The scar beneath Head House, at the entrance to Great Fryup, shows 5 feet of ferruginous Dogger on an irregular surface of white false-bedded sandstone. This sandstone, which reaches a thickness of 15 feet, is probably only an exceptional modification of the more usual ferruginous Dogger.

In Little Fryup, though the Dogger can be traced easily, there are no good sections.

On the west side of Danby Dale the Dogger and Lias are so similar in lithological character near the junction that it is difficult to draw an exact line between them. A section close to Double Dike shows :—

	Feet.
Estuarine shale and a little sandstone. Shaly Dogger	12
Shale	5
Very shaly Dogger with undeterminable *Ammonite* (the lower 2 or 3 feet may perhaps belong to the Lias) Alum Shale.	12
Total	29

In the main valley of Westerdale the only evidence of the existence of the Dogger is in the road cutting at Top End near Westerdale Village. The section shows :—

	Feet.
Sandstone (estuarine). Shaly Dogger Alum shale.	13

Beneath Esklets Crag this has changed to a flaggy micaceous sandstone with wood, small *Avicula,* and an undeterminable *Ammonite.*

Probably a similar change prevents the Dogger from being clearly identified in Basedale. At the head of Black Beck the section is :—

	Feet.
Flaggy sandstone, the lower part with oolitic ironstone, ferns, and much lignite about	30
Shale, with *Ammonites communis*	6
Total	36

In the neighbourhood of Kildale the Dogger, or, as it is often called about here, the "Top Bed," consists of a 10-inch band of hard ironstone, containing *Pholadomya Heraultii ?* in great numbers, resting upon 5 feet of marly, shelly stone that decomposes on exposure to the air. About 2 feet down this latter bed contains lines of apparently waterworn nodules, which are somewhat phosphatic, and which towards the base of the stone are extremely abundant.

Passing round to the south, in the Ingleby escarpment, shales with rows of nodules and fragmentary fossils are the only representative of this bed, and, there being so many clear exposures of the junction of the Lias and Oolite, the absence of any characteristic bed is very marked. On the west side of Hasty Bank the Dogger, which comes in as a wedge, assumes the character of a ferruginous shelly limestone, and continues as such for a great distance to the west and south-west.

Section of the Dogger at Wain Stones, Hasty Bank.

	Ft.	In.
Ferruginous dark shale	15	0
Shale with ferruginous Doggers	3	0
Very ferruginous limestone	0	6
Soft, dark shale	3	9
Limestone, flaggy, oolitic, ferruginous, full of comminuted shells	3	0
Soft, dark shale	0	4
Ferruginous, calcareous, nodular bed	2	0
Shale, with water-worn *Belemnites*, &c. (Pebble bed)	2	0

On the west side of Bilsdale, about a mile due south of Wain Stones, the Dogger presents a very unusual and interesting appearance. It is a strong encrinital limestone with many fossils, principally *Terebratula trilineata, Modiola imbricata, Trigonia* sp. and *Pleurotomaria calix*, having a thickness in one place of about 20 feet; it lies in a distinctly eroded hollow in the Upper Lias, this hollow being more than a mile in length; and in one place, just out of the area here described, the limestone descends to within 30 feet of the Jet Rock.

Throughout the rest of Bilsdale the only representative of this bed is the shale with one or more rows of ferruginous nodules; and in some cases the Estuarine Sandstone rests immediately upon the Alum Shale.

In Bransdale sections are confined to the south portion of the dale, the best being one south of Stork House, which gives:—

	Feet.
Estuarine shale	5
Fine-grained, dark, flaggy sandstone	25
Alum shale.	
Total	30

The only places where the Dogger can be seen in Farndale are in the immediate neighbourhood of the mines above the Church,

which were opened in the hope of obtaining the valuable magnetic ironstone worked in Rosedale. The Dogger appears to be about 25 feet thick, but thins out rapidly in both directions. A trial hole on Blakey Moor showed only 5 feet of poor ironstone.

In Rosedale the Dogger has been extensively worked for ironstone, but the distribution of the stone is curiously partial. At the head of the dale the beds are so different from those a mile away that, had they not been traced continuously, it would be difficult to recognise them as belonging to the same horizon. A section in the stream near Black Intake shows:—

	Ft.	In.
Flaggy sandstone with *Avicula*, wood, and ironstone with shale	10	0
Hard shale	8	0
Line of tough ironstone shale with *Belemnites*, and small tough nodules	0	6
Alum shale.		
Total	18	6

To the south-east the ironstone improves, and has been extensively worked in Rosedale East Mines. A quarried face at Moor Hill exposes:—

		Ft.	In.
	Carbonaceous shale and rubbly sandstone	10	0
Dogger	Sandstone, soft, fine-grained, with white specks	9	0
	Hard, blue, very micaceous shale, very like Lias	4	8
	Ironstone, tough and poor, with white nodules, often left as roof in the mine	1	0
	Ironstone, fossiliferous, oolitic, rather poor	3	0
	? (hidden)	2	0
	Ironstone, very poor and soft, full of casts of *Belemnites*—the "Belemnite" of the miners	7	0
	Ferruginous sandy shale with casts of *Belemnites*	7	0
	Alum shale	10	0
	Total	53	8

The workable ironstone in the East Mines varies from 4½ to 14 feet, averaging, according to the manager, about 6½ feet. About 130 acres have been worked out. Analysis gives:—

Iron	32·70
Siliceous matter	9·27
Phosphoric acid	1·64
Water	6·30
Loss by calcination	28·30
Iron in calcined stone	45·60

For a short distance there is a seam of magnetic stone about 14 inches thick, containing *Pecten demissus*, Phil., and yielding:—

Metallic iron	37·20
Loss by calcination	18·50
Silicious matter	10·40
Iron in calcined stone	45·60
Moisture	0·44

This was the only magnetic ironstone found in the East Mines. It formed a lenticular mass in the ordinary stone, and showed a similar oolitic structure.

On the opposite side of the dale, near Sherrif's Pit, the seam is much more regular, measuring about 6 feet. Analysis gives:—

Iron	36·60
Silicious matter	8·44
Phosphoric acid	1·27
Water	8·20
Loss by calcination	28·80
Iron in calcined stone	47·20

In the West Mines the most valuable stone is a magnetic ore lying in two narrow channels or troughs cut in the Alum Shale. These masses of magnetic ironstone, forming an abnormal thickening of the ordinary Dogger, are known respectively as "Kitchen's Deposit" and "Garbutt's Deposit." They are about 70 feet thick in the centre, and extend in a south-westerly direction about a quarter of a mile into the hill. Though worked for a good many years there is still, according to Mr. Roscamp's estimate, about 200,000 tons left. No other channels, or continuations of these, have yet been discovered, but the most probable place for finding them, on the opposite side of the dale immediately north of Mill Farm, appears not to have been tried. The average of a number of analyses of the magnetic stone gives:—

Peroxide of iron	32·56
Protoxide of iron	25·92
Protoxide of manganese	0·22
Alumina	7·13
Lime	2·84
Magnesia	1·82
Silica	7·03
Carbonic acid	9·38
Sulphur	0·02
Phosphoric acid	1·57
Carbonaceous matter	0·56
Combined water	4·88
Moisture	6·20
	100·13
Metallic iron	42·95
Loss by calcination	18·06
Iron in calcined ore	52·42

Lower Estuarine Series.—Between the Dogger and Grey Limestone Series there is about 289 feet of estuarine sandstones and shales, with occasional fireclays and thin coals. Drift wood, which has frequently been converted into an inferior kind of jet, is abundant, and ferns often occur, though there is a curious scarcity of other fossils. No freshwater shells have yet been found in this district, but upright *Equisetites* are sometimes seen in the fireclays and sandstones. The sandstones continually change or die

out, so that no bed can be traced for any great distance. There is often a thick bed, making a distinct feature, a short height above the Dogger, and sometimes cutting into the Dogger, but neither this nor any other bed is to be trusted as making a definite horizon. Unfortunately, in this area there is a dearth of clear exposures of any magnitude, and only one of the pit sections has been preserved by which we can obtain a general idea of the thickness and character of the beds.

At the Castleton Road shaft of the Rosedale East Mines a continuous section from the Grey Limestone to the Dogger was laid open, and Mr. Roscamp has given the following details:—

		Ft.	In.
	Surface matter	2	6
[Grey Limestone Series.]	Grey shale	5	8
	Freestone	3	2
	Grey shale	4	8
	Freestone	2	6
	Blue shale	12	0
	White sandstone	3	6
	Grey shale	4	6
	Grey post	2	6
	Grey shale	1	6
	Grey post	2	6
	Grey shale	6	0
	Grey post	8	0
	Grey shale (clayey)	8	0
	Grey post	2	0
	Grey shale (hard)	8	0
	White post	1	0
	Coal	1	6
	Coal, shale, and fireclay	1	6
	Grey post	7	6
	Dark shale	3	6
	Grey post	4	0
	Grey shale	10	0
	White post	1	0
[Estuarine Series, 275 feet 8 inches.]	Grey post	14	0
	Grey bed (shale and post)	4	0
	Dark shale	13	0
	Grey shale (very hard)	13	0
	White post	8	0
	Blue post	2	0
	Dark shale	10	0
	Blue post	3	0
	Blue shale	5	0
	Grey post	4	0
	Grey bed (shale and post)	7	0
	Grey shale	4	0
	Grey bed (shale and post)	21	0
	Dark shale	14	0
	Sagger or fireclay	8	0
	White post	3	0
	Grey shale (hard) spavin	3	0
	Grey shale	12	0
	Grey post	5	0
	Grey shale	9	0
	Grey post	4	0
	Grey shale	4	0

		Ft.	In.
[Dogger.]	Freestone	10	0
	Dark shale	4	6
	Ironstone (blue)	11	0
	Total	302	6

In the Grosmont district there is, about 30 feet above the Dogger, a great mass of sandstone, sometimes as much as 60 feet thick, which makes a very bold feature along the valley. This rock is quarried above the Alum Works just at the east of this area, and it also shows very well on the north side of the Esk, under Swarth Howe Cross. To the south it passes through Crag Cliff Wood and up Eller Beck, where there is a complete section of all these beds, though there is no point of special interest about them. The sandstones are, for the most part very felspathic, which does not permit their resisting much pressure, and, when this is the case, renders them unfit for building purposes.

In the western area it is very noticeable that the strata, as a rule, are more arenaceous, the sandstones forming by far the larger part of the Estuarine Series. The section under Burton Head, where the Alum Shale is succeeded by 110 feet of sandstone with mere partings of shale, shows this very well; the sandstone giving a very bold outline to the escarpment. On the edge of Ingleby Moor there is a very large quarry in this sandstone, but in Bilsdale these beds are not well developed, as a rule, although there is a very bold crag of the thick sandstone in Tripsdale; and, on the west side of the dale, just above Helm House, where the uppermost part of the bed is more even and finer grained, it was once quarried extensively and furnished the stone from which Rievaulx Abbey was built.

The Eller Beck Bed.—Rather more than 100 feet above the Alum Shale is a thin marine bed known as the Eller Beck Bed.* This bed may be described as a flaggy, fossiliferous sandstone, or sometimes oolitic ironstone, resting on shales in which occur either nodules or thin continuous beds of very fossiliferous ironstone. Both its upper and lower boundary is indefinite, there being a gradual passage into the ordinary estuarine beds.

Commencing with the north side of the Esk, the first exposure met with is in the beck below Egton Village; but, though masses of the fossiliferous ironstone can be found, there is no clear section. At Lealholm, in Trinket Wood, and also close to the Station, the ironstone re-appears, but again slightly out of place.

South of the Esk the Eller Beck Bed forms a very convenient horizon in the thick series of Estuarine Beds. It is probably continuous, for wherever sections occur in the right place there is little difficulty in recognising the bed.

* See G. Barrow, *Geol. Mag.*, dec. II., Vol. iv., p. 552.

The first section of any importance is the typical one in Eller Beck at Walk Mill Force below Darn Holm. The section here is :—

		Ft.	In.
a.	Sandstone, hard at top, flaggy at base, with a few impressions of *Modiola* and *Avicula*	10	0
b.	Shale, ferruginous and sandy	4	0
c.	Hard ironstone	0	5
d.	Ferruginous Shale	5	0
e.	Ironstone full of comminuted shells	1	2
f.	Shales.		

The bed of ironstone (*e*) contains a considerable variety of fossils, of which a list is given at page 35; *Pholadomya Heraultii?* and *Myacites* in a vertical position being very abundant. This bed, which was first noticed by Bewick,* is locally known as "Julian's line," as it is supposed to have been worked by the Romans; it is very hard, and gives on analysis :—†

	No. 1 (*c*).	No. 2 (*e*).
Protoxide of iron	38·87	32·62
Peroxide of iron	·41	·13
Protoxide of manganese	·08	·16
Alumina	·89	1·99
Lime	2·40	1·70
Magnesia	2·63	2·56
Sulphur	·35	·19
Sulphuric acid	trace.	trace.
Phosphoric acid	·19	1·74
Carbonic acid and organic matter	25·17	20·53
Total water	2·30	2·10
Ignited insoluble residue	24·40	33·70
	98·41	97·42
Silica in insoluble residue	21·70	30·70
Alumina with a little lime and magnesia	2·70	3·00
Iron in raw sample	30·52	25·40
Lost by calcination	23·50	19·20
Iron in calcined stone	39·89	31·51

This lower seam has been followed with occasional small gaps over a very large area. It has not been recognised to the north-east of Eller Beck, but re-appears on the south of this preglacial valley at Mollion Spout and may be traced along the face of New Wath Scar, where the flaggy sandstone has cores in the middle composed of grains of sand enveloped completely in oxide of iron, being, in fact, almost an oolitic ironstone. The ironstone bands below are thinner, and only the lower one contains many fossils. This section may be followed as far as the junction of Wheeldale Gill with Wheeldale Beck. In the former stream the sandstone alone is visible for a considerable distance, but above Archy Crag the first seam of fossiliferous ironstone, 8 inches thick, appears and another is seen a little higher up, which continues for nearly a mile before they finally disappear.

On the west side of the Murk Esk these beds are seen in Grain Beck, where the following section was measured :—

* Geological Treatise on the District of Cleveland, p. 67, 1861.

† Furnished by Mr. Bagnall of Grosmont.

	Ft.	In.
Hard sandstone	4	6
Oolitic ferruginous sandstone, almost an ironstone	2	0
Flaggy sandstone	2	6
Shale	3	0
Ironstone band	0	2
Shale	3	0
Ironstone band	0	6

About a mile further north in Oakley Beck the sandstone is seen, and, as is shown by the "Cinder Hill," at Narrow Stye End, has evidently been tried as an ironstone. North of this the outcrop is not very clear, although its position is tolerably well fixed by the feature formed by the sandstone above.

Passing round by Egton Grange there is a clear section at the head of the dale in Birchwath Gill, where the typical flaggy sandstone is seen with the shale and fossiliferous ironstone seams below. The section here is:—

	Ft.	In.
Flaggy sandstone	10	0
Shale, with two rows of fossiliferous ironstone at the base	4	0
Total	14	0

On the west side of the dale the feature of the sandstone can be followed to the "Pits" at Holey Intake above Arnecliffe Wood where the ironstone in it has in former times been worked. About a mile to the south-west very silicious oolitic ironstone is seen in a small ditch, and the sandstone, which is very fossiliferous, crops out in the road above Gill Beck.

In Winter Gill the Eller Beck Bed attains its greatest known thickness. The following section was measured here:—

	Ft.	In.
Very hard, close-grained sandstone containing fragments of soft jet and other carbonaceous matter	4	0
Ironstone, sandy and impure	1	0
Ironstone, dark brown, oolitic, slightly magnetic; fossils extremely rare	6	0
Calcareous and ferruginous stone, with a few small fossils	2	0
Hard, flaggy, micaceous, white sandstone, passing gradually downwards into a sandy shale	20	0
Sandy marl	1	6
Dense limestone, apparently unfossiliferous	0	4
Argillaceous micaceous shale, much resembling the shales of the Middle Lias	5	0
Ironstone with abundance of the characteristic *Pholadomya* and other fossils*	1	0
Total	40	10

The position of this section can be fixed by the old drifts into the stream banks and by the presence of a heap of the oolitic ironstone in the beck. The ironstone varies much in thickness, reaching 13 feet at the shaft, but changing so fast that it cannot be depended on. It probably soon dies out entirely in each

* *See* List of Fossils, p. 35.

direction. An analysis of the magnetic ore by Mr. W. Morgan gives :—

Iron	36·78
Silica	11·06
Alumina	4·96
Phosphoric acid	1·68
Lime	3·21
Magnesia	1·60
Sulphur	·33
Iron in calcined stone	47·00
Loss by calcination	22·78

On the west side of Glaisdale, close to High Hardhill, there is the following section :—

	Ft.	In.
Flaggy sandstone and shale	15	0
Shale	4	0
Ironstone, fossiliferous*	0	11
Shale	1	0
Total	20	11

A little further north in the "Sandstone Quarry" above Hardhill where the Eller Beck Sandstone has somewhat the character of the oolitic ironstone of Winter Gill there is :—

	Ft.	In.
Sandstone and shale with *Equisetites*	3	0
Flaggy very sandy oolitic ironstone	2	6
Thick sandstone	6	0
Total	11	6

Above Post Gate Hill the Eller Beck Bed has been tried at two places for ironstone. The easterly hole has fallen in, but the westerly one shows shale with three rows of ironstone.

Nearly due north of this at the point where the Whin Dyke crosses Buscoe Beck at Low Wood the Drift has been cut through and a section immediately south of the Dyke shows :—

	Ft.	In.
Thick sandstone	6	0
Shaly sandstone with soft jet	10	0
Shale and soft grey sandstone	2	6
Ironstone with carbonaceous markings	0	1
Micaceous flaggy chert	1	0
Shale and thin chert	2	8
Two thin irregular ironstones, unfossiliferous	0	4
Shale	3	4
Ironstone full of fossils, *Astarte minima*, *Trigonia*, *Ostrea*, *Myacites*, *Pholadomya*, *Pinna*	1	5
Shale, lower part estuarine	4	0
Total	31	4

* A quarter of a mile south of High Hardhill this ironstone contains *Astarte minima*, *Gervillia* sp., *Ostrea* sp.

It is not clear how much of this section belongs to the Eller Beck Bed.

On the south side of the Esk at Crankly Gill the fossiliferous ironstone is again seen, but is very silicious.

In Fryup, the only place where the Eller Beck Bed has been recognised is at the head of Great Fryup, where the fossiliferous sandstone forms a low cliff for about a mile. The fossiliferous ironstone, however, cannot be traced here.

Near Danby Dale and Westerdale, this marine bed being high up on the moors there is a scarcity of sections. There is a small exposure between these dales at Stone Ruck Hill, and another in the Sandstone Quarry, a quarter of a mile further south, where we find :—

	Feet.
Flaggy sandstone, full of fossils and wood, and with traces of oolitic ironstone : *Pecten, Ostrea, Trigonia, Astarte minima*, &c.	13

The fossiliferous beds are also found at two or three points on the moors round Westerdale, so it is probable they are continuous over the whole district, though not always recognised.

In the neighbourhood of Basedale, although there are no sections of the Eller Beck Bed, it can easily be traced round the sides of that dale and across the moors to the Ingleby escarpment, when the outcrop divides into two branches, one turning north above Park Plantation, the other south under Burton Howe to the Incline Top. The incline here was originally made to work the ironstone in this bed, and it is evident that it must have been somewhat thicker at the outcrop to have warranted such an outlay. The section here is :—

	Ft.	In.
Soft sandstone with very large vertical *Equisetites* and soft jet	10	0
Reddish-brown shale, coaly at base	10	0
Thin, hard, flaggy sandstone	3	0
Finely laminated shale	2	0
Ironstone with fossils	0	9

Continuing along the escarpment, where the outcrop is fairly clear, there is a fine section in Blue Bell Trough, showing :—

	Ft.	In.
Estuarine sandstones and shales	50	0
Thin, flaggy sandstone	3	0
Shales, bluish and well bedded	6	0
Ironstone with minute fossils	2	0
Shale 1 ft. 0 in. Ironstone 0 4	1	4
Shale 1 6 Ironstone 0 6	2	0

Passing round into Bilsdale, the Eller Beck Bed gradually becomes thinner and untraceable for some distance down the dale, but opposite Chop Gate a small band of ironstone crosses the road above William Beck; this is, however, quite an isolated outcrop. In Fangdale Beck this band of ironstone is 2 feet thick, with the typical flaggy sandstone and shaly sandstone with soft jet above.

North of this point the outcrop is clear for some distance, but it is soon lost to the south. On the opposite side of the dale the ironstone is exposed in the roads above Low Crosset, and can be traced some distance to the south.

In Bonfield Gill, close by the road into Bransdale, fossiliferous flaggy sandstone is seen, and further up the shale, with a foot of ironstone: the position of the bed can be clearly followed on both sides of the dale till it enters the stream again some distance above the last intake.

There are no sections of the Eller Beck Bed in Bransdale or Farndale, but a marked feature and occasional fragments of fossiliferous grit allow the bed to be traced nearly continuously.

Rosedale shows several good sections. The first in the "Crag" south-west of Rosedale Abbey shows:—

	Ft.	In.
Sandstone	20	0
Shale	7	0
Fossiliferous Ironstone dogger	0	6
Shale	1	0
Ferruginous fossiliferous grit	2	0
Estuarine shale and thin sandstones	30	0
Total	60	6

The other exposures are in Northdale, where the Eller Beck Bed forms a bold scar above the stream. A section near Coal Pit Hill shows:—

	Ft.	In.
Estuarine shale and thin sandstone.		
Flaggy sandstone with plants and *Avicula*	3	0
Shale	3	0
Ironstone, fossiliferous with *Myacites*, *Astarte*, *Pholadomya*, *Ostrea*, *Gervillia*	0	6
Shale.		
Total	6	6

In North Gill it has altered to:—

	Ft.	In.
Sandstone, flaggy at base and full of fossils	17	0
Shale with line of tough nodules	6	0
Ironstone with *Pholadomya lyrata* or *P. Heraultii*	0	6
Estuarine shale	11	0
Shale and shaly sandstone.		
Total	34	6

The Eller Beck Bed also outcrops in the upper part of Hartoft Beck below Low Hamer, and may be followed down the valley as far as Wash Beck House.

The following is a list of fossils collected from the Eller Beck Bed:—

Astarte minima, Phil.
Cardium lingulatum, Lyc.
„ sp.

Corbis elliptica, (Whiteaves MSS.) L. and M.
Corbula involuta, Münst.
Cypricardia, sp.
Cyprina, sp.
Exogyra, sp.
Gervillia prælonga, Lyc.
„ *lata*, Phil.
„ sp.
Ostrea, sp.
Pecten lens, Sow.
„ sp.
Pinna cuneata, Phil.
Myacites decurtata, Phil.
„ *modica*? Bean.
Pholadomya acuticostata, Sow.
„ *lyrata*, Sow. or *P. Heraultii*, Ag.
Tancredia axiniformis, Phil.
Trigonia, sp.
Unicardium, sp.

Cerithium?
Kilvertia.
Phasianella, sp.

Coal Seams.—The estuarine sandstones and shales above the Eller Beck Bed are not of much interest, except for the occurrence in the upper part of a small seam of coal.*

Though there are several thin coals at different horizons in the Estuarine Series, the only one which can be traced or has been worked for any distance is about 60 feet below the Grey Limestone. Here and there other seams have been mined for a few hundred yards, but they soon die out. The coal seam beneath the Grey Limestone varies in the workings from 11 inches to 2 feet. Where less than 11 inches it is not worth working, and it only reaches 2 feet for a few hundred yards, the average cannot exceed 14 inches. The only pits at present worked are at Poverty Hill, near Danby, where the seam sometimes yields 13½ inches of coal, and at Rudland Slack, south-west of Farndale. The extreme thickness of 2 feet was found in the old workings on the east side of Blakey Ridge. A mile north the seam measures 15 inches, two miles south it thins to 8 inches.

In Eller Beck, this seam outcrops for a short distance above Walk Mill Force, where a few pits have been sunk to it, and the beds above, which consist principally of shales with plant remains, may be well studied in the banks of this stream.

* The "Millepore Bed," so important in the coast section, is either entirely absent or only represented (as a marine deposit) at one or two points in this map. Mr. Hudleston believes that he has recognised it near Goathland (*Proc. Geol. Assoc.*, Vol. iii., Part I., p. 310). It is, however, possibly represented by an 8-inch seam of oolitic ironstone which occurs in Winter Gill about 100 feet above the Eller Beck Bed.

The next good outcrop of the coal is above Danby Station where the seam was exposed in a small gulley near Lop Hall, and the following section which gives a fair view of the nature of this part of the Estuarine Series was measured :—

		Ft.	In.
Grey Limestone Series.	Soft encrinital sandstone	2	0
	Sandy ferruginous shale	4	0
	Hard silicious and ferruginous sandstone with *Gryphœa*, &c.	8	0
Shaly sandstone		10	0
Blue and white shale		3	0
Soft carbonaceous sandstone		5	6
Fireclay		3	0
Sandy shale		2	6
Soft, brown, micaceous sandstone		14	0
Grey shale		5	0
Blnish-grey sandy shale		4	2
Flaggy sandstone		4	6
Coal Seam	Coal 7½ ins. / Shale 5½ ,, / Coal 6 ,,	1	7
Underclay		1	3
Shaly sandstone with vertical *Equisetites*		1	6
Sandy shale		3	0
Sandstone		2	6
Shale with jet or pipecoal		15	0

The coal has been worked at Oakley Walls, south of Danby Beacon, and may be traced from thence by Poverty Hill to the head of Clither Beck near Doubting Castle. On the west side of this valley there are not many old pits, which looks as if the coal was poorer; but on the opposite side of the hill, at Lop Hall, it has been worked again for a short distance.

On the south side of the Esk Valley the coal has been worked in former times at Wintergill, on Glaisdale Ridge, at the head of Fryup Dale, and at the head of Danby Dale; and the outcrop may be traced fairly well between these places, although the coal itself is only seen in a few imperfect road-sections on either side of Fryup Dale and on Westerdale Moor. South of this latter the outcrop runs round to the south, and has been somewhat extensively worked on the moors above. On Blakey Moor the coal attains its greatest thickness, there being as much as 2 feet here, although at the head of Rosedale there is not more than 15 inches, while in the Castleton Road shaft of the Rosedale East Mines there is as much as 18 inches. Further east this bed has been worked at Hamer and above Hazel Head, there being an inlying outcrop of the coal in the beck to the north of the former place, and the coal itself is seen on the road just above.

About Ingleby, where as a rule only the lower portion of the beds above the Eller Beck Ironstone are present, the strata are much more arenaceous, and there is no evidence of the coal being present. Towards the lower end of Bilsdale, however, on the west side above Wether Cote, and also on the East Moors, this coal has been extensively mined; it is seen in Bogmire Gill just below Hazel Green, north of which its course may be fairly well made

out both by the position of the Limestone above and the various coal pits, the latter being very numerous about Old Kiln and Piethorn. From information, the coal here is in two beds 11 inches and 4 inches thick respectively, and about 60 feet below the Grey Limestone Series.

At Harland, to the south-west of Farndale, this coal has been largely worked. It is here only 8 inches thick, but is better for house purposes than that at Piethorn.

Another very thin coal often occurs a few feet above the Dogger, and upright *Equisetites* are sometimes found on the same horizon. This is probably the coal that has been worked near Spires House at the south end of Rosedale, and a very local seam about 70 feet higher has also been worked at the head of Basedale. The following account of shafts and borings* which seem to have been sunk in search of this coal, but did not pass through it, show how very uncertain this seam must be:—

Coal Sinkings at Baysdale, 12 miles from Whitby.

No. 1.

	Ft.	In.
Sand and gravel	4	4
Brown sandstone	3	0
Metal	3	0
White freestone	4	6
Blue metal	3	0
Blue bind	1	6
Blue metal	3	0
Blue flinty stone	1	5
White freestone	10	6
Blue metal	4	6
White freestone	27	0
Blue metal	1	0
White freestone	4	6
White freestone	16	6
Blue metal	3	0
White freestone	1	0
Blue metal	1	4
White freestone	0	6
Blue metal	1	6
White freestone	11	2
Total	106	3

No. 2.—Sinking.

	Ft.	In.
Walling from the surface	10	6
Drab-coloured stone	19	6
Blue metal	34	6
White freestone	4	4
Blue metal	9	0
White post	1	8
Blue metal	6	0
Here coal was expected.		
White freestone	21	0
Total	106	6

* Winch. *Trans. Geol. Soc.*, Vol. v., p. 551.

Boring from the bottom of the pit.

	Ft.	In.
White freestone mixed with blue whin	12	0
Rag stone	20	0
Alum shale	15	0
Total	153	6

No. 3.—Boring.

	Ft.	In.
Peat moss	4	0
Blue clay	6	0
Blue metal	3	0
White freestone	1	6
Blue bind	10	6
Blue metal	1	6
White stone	4	0
Blue stone with coal pipes	6	0
Blue metal with post girdles	6	0
White freestone	4	6
Blue raggy stone	4	6
Dark brown post with water	9	0
Blue metal mixed with ironstone balls	4	0
Total	64	6

Left off at a coarse white post with a large feeder of water.

Valuable sandstones for building have been quarried, or can be found, over the greater part of the moors. The best beds occur in the lower part of the Estuarine Series, between the Eller Beck Bed and the Dogger, forming lenticular masses sometimes several miles in length and 20 or 30 feet thick. Other quarries yield good flagstones and gate posts. The freestone varies from a coarse hard grit to a rather fine-grained sandstone. Though almost universally used for building in the district, it has the disadvantage of being very porous until a coating forms on the surface. The colour is good, generally pale buff, but often spoilt by stains of iron oxide appearing after the stone has weathered.

Some of the most extensive quarries are on the north side of Glaisdale, on Danby High and Low Moors, and south of the Esk near Egton. A quarry near Moor Hill End produced the excellent white freestone of which the Roman Catholic Chapel at Egton Bridge is built. Other large quarries are worked on Rudland Moor, and near Rosedale Abbey. For road-metal the sandstones are quite unsuited, as they rapidly crush into sand; these are extensively used, but whinstone or slag are substituted where the cost of carriage is not too great. The most calcareous beds of the Grey Limestone Series are also used locally to a considerable extent, especially about Spindle Thorn as mentioned in the description of these beds.

Grey Limestone Series.—In the eastern part of the Map the beds of this series are very similar to those described in the Explanation of Quarter-Sheet 95. N.W. being mostly fossiliferous

shales with thin silicious and calcareous bands and thin beds of ironstone; but towards the west the beds become much more arenaceous and thick fossiliferous grits set in, which entirely alter the character of the outcrop and cause a marked change in the aspect of the country.

In the neighbourhood of Grosmont and Goathland the outcrop of these beds is chiefly made out, either by that of the hard, white, Moor Grit above or by the small ferruginous nodules with *Avicula braamburiensis* that occur quite at the top of the series. These nodules occur in shale which is about 15 feet thick and is succeeded by calcareous sandstone or grit about 10 feet, and then calcareo-argillaceous beds about 5 feet. At the outcrop the grit has a very porous appearance owing to the dissolution of the lime, and it is only in very clear and steep sections, such as occur in streams or quarries, that the calcareo-argillaceous beds are seen.

The shales with nodules are exposed for some distance above the bank at Goathland Mill, and part of the calcareous beds may be seen in the small stream just above Abbot House. The best section, however, is just beyond the eastern edge of the map in Eller Beck where the Whitby road crosses that stream, and in the railway a little to the west; at this latter place the sandstone above these beds is well seen, and the calcareous shales themselves are exposed for some distance in the cutting, and may be traced along the edge of the moor to Killing Pits, where the ironstone from these beds seems to have been smelted in very ancient times. A good deal of mystery hangs over these "pits," and various theories have been started to account for their origin. Bewick recognised that they were the remains of mining operations but erroneously attributed the ore to the Kellaways Rock.*

The outcrop may be easily traced beneath the great scars on either side of the beck south of Hunt House, and thence, skirting along the southern edge of Wheeldale Gill, crosses that stream near its upper end and divides into two portions, one of which spreads out in a large area over Egton High Moor to the north; the other turns south and follows the escarpment on the east side of Hartoft Beck to Spires Bank, where, owing to the strong southerly dip, the beds plunge down into the stream in a very short distance.

In the banks of the river Seven the beds although seen afford no continuous section, and rising rapidly on the further side of the stream pass by the old "Smelting Works," where again this ironstone seems to have been worked in ancient times. On Spaunton Moor owing to the steep dip the outcrop of the Grey Limestone runs up into a series of points or nabs between the numerous streams coming down off the moor. In a quarry on one of these nabs at Spindle Thorn there are about 12 feet of shale over 5 feet of dense hard blue silicious limestone; this limestone,

* "Geological Treatise on the District of Cleveland," p. 77, 1861. Quoted by Hudleston. *Proc. Geol. Assoc.*, Vol. IV., p. 368.

which is quarried for road-metal, has rather, a peculiar appearance and when freshly broken by the roadside might, from its dark colour and dense structure, be easily mistaken for whinstone. In some places the limestone decomposes rather readily, especially along lines of joint, so that usually when seen in section the rock has more the appearance of a line of large boulders than a continuous bed; from this cause the outcrop is often difficult to follow, as what may be good strong rock at one place is often mere clayey sand a little further on. About Spindle Thorn, however, a strong fossiliferous grit begins to come in below the limestone, which forms a good spread on the moors, and allows the outcrop to be traced without difficulty further west.

Most of the small becks which cross the outcrop afford good exposures of these beds, especially a small ditch called "The Gulf" on the east side and Harland Beck on the west side of Farndale; the first of these shows the hard blue limestone resting on calcareous sandstone very fossiliferous, the whole capped by about 120 feet of shale.

West of Farndale a thick fossiliferous grit appears in the upper part of the Grey Limestone Series and forms great spreads often more than a square mile in extent, capping the ridges and watersheds between the various dales. This causes a great change in the character of the country; for where these great spreads of fossiliferous grit occur, long, flat, dip slopes are seen, which are usually very dry, except where covered by peat, and the wet estuarine clays have a much narrower outcrop; but further east, where this grit is absent, a large area is formed of low rounded hills of the higher estuarine strata, with simply a belt of the Grey Limestone Series beneath; the country being bleak and wet in the extreme. About Swinacle this grit makes a small spread before descending to Rudland Beck, where the limestone is seen beneath, and the beds may be followed down this beck to its junction with the Hodge Beck at Pennyholme Wath. A few yards further up the main stream is a small gill, at the bottom of which the limestone beds are exposed. From this point the outcrop of the grit passes just along the top of Mitchell Hagg Wood to the Ordnance Station 1,072, at Lambfold Hill, on the west side of Bransdale, the bed being close to the surface, and almost bare for a considerable distance.

In Bonfield Gill, at the low end near Throstle Nest, the grit with encrinites is exposed under the footbridge. Bogmire Gill is encircled by the outcrop of these beds; and, where they approach the stream at the south end of the valley, several good sections are seen, the best being in a gully just below the road at the end of the most southerly intake. Here may be seen some 20 feet or more of shales, then a few feet of hard, blue limestone, below which comes the fossiliferous grit about 10 feet thick, and then the blue limestone at the base, the exact thickness of which cannot be seen. A little further south these limestone bands form the bed of the river for nearly 50 yards and can be well examined. They are, however, not so fossiliferous here as they are further east.

There is an inlier of the Grey Limestone Series at Snaper House, this little valley being almost composed of these beds. The blue, flinty limestone, which must be at least 10 feet thick, and is much used locally for road-metal, is exposed just below the junction of the two branches of the stream. On the moors to the north these beds make a great spread, running up as far as the Ordnance Station 1197, where an old limekiln may be seen which was erected to burn the flaggy limestone that occurs below the grit, and is unusually well developed in this area. Generally the quantity of water percolating through the porous grit is so great that this limestone is mostly dissolved away at the outcrop. On the western side of this area there are two small faults one of which cuts out the outcrop for some distance.

At Carr Cote the Grey Limestone makes a small spread, and, passing round below Rosy Dike where there is a section, dips rapidly into Bilsdale, the outcrop being very clear all about here and well exposed where it crosses the main road a quarter of a mile south of Laskill. Just south of here the beds enter the river and form a fine scar just below Grimes Holme.

On the west side of Bilsdale the outcrop follows the edge of moor, and the three divisions of shale, grit, and calcareous beds are very distinct, and can be followed for some distance.

There are several outlying patches of the Grey Limestone Series, the one in the centre of the map at the head of Rosedale being of considerable size.

On the north side of the Esk there is a long outcrop of these beds, which skirts round the north face of Egton Low Moor, but is completely concealed by drift, the flaggy part of the Moor Grit near Fishburn's Plantation being the only clue to its position. Passing by an obscure course round Egton village, the first clear exposure is in a small gill above the old church, where fossiliferous shales are seen; the Moor Grit in the next gill fixes the position and continues to do so for a considerable distance.

On the west side of Stonegate Gill the fossiliferous grit caps the great scar almost along its whole length; but turning round to the west above Lealholm exposures are rare as far as Wall Corner, where the grit is seen in a little gutter above the house, and the shales with *Avicula braamburiensis* are exposed a few yards further west. The various coal pits here show very clearly what a large portion of the calcareous beds are completely dissolved away at the outcrop; for in one of these shafts strong beds of calcareous sandstone and impure limestone are seen having a thickness of from 15 to 20 feet. The exposure at Lop Hall has already been referred to in the section on page 36.

The smaller outliers, of which, however, there are a great number, do not call for particular notice.

The Upper Estuarine Series.—The Grey Limestone is succeeded by a considerable thickness of shales with thin bands of very hard, close-grained sandstone, having at the base a thick bed of massive sandstone, which from its importance has been mapped separately. This bed, the "Moor Grit," follows the outcrop of the Grey Limestone, and, as we have mentioned above, is sometimes the only means of tracing that rock.

About Grosmont the Moor Grit is by no means a strong rock and consists principally of thin white flags. On the north side of the Esk, west of Egton, this bed becomes much stronger and harder, and contains wedges of fine-grained, silicious, almost glassy, rock, which has been extensively quarried for road-metal near Westonby House, near Stonegate, and by the side of the road above Lealholm Bridge.*

The Moor Grit maintains the same character throughout the whole of its outcrop along the north side of the Esk. In the southern area it varies very much, the quartzite looking beds being only occasionally visible; in which case the moor is strewed with white blocks having a very glassy looking surface. Below this part of the bed is a solid white freestone, which becomes very hard on exposure to the atmosphere and affords an excellent building stone. Being well bedded it is fairly easily worked, and was quarried at Old Fold on Helmsley Moor to build the bridges of the North-eastern Railway between Helmsley and Pickering, which structures are evidence of the fine blocks that can be obtained from it.

The sandstones occurring throughout the Upper Estuarine beds are quite unlike those below the Grey Limestone Series; for, while the latter are very felspathic and easily crushed, the thin bands above that bed resemble the Moor Grit in being remarkably free from that mineral and very hard. The shales are almost destitute of lime and soluble salts, and form in consequence a very cold, hungry soil. The chief point of interest about them is that they make excellent bricks, as may be seen at the works in the hollow close by the old Egton Racecourse. When the moor on which these beds outcrop is clear of drift their presence may be at once inferred from the number of little gullies or deep ditches with white sides which may be seen a long way off, notably on Danby Moor. Except that they are here somewhat thinner, and contain rather more sandstone, these Estuarine Beds offer no point of interest on the Helmsley Moors.

The Cornbrash.—The Cornbrash has a greater thickness in this map than it has previously attained in any other portion of its outcrop, and consequently the finest sections of this rock that are exposed anywhere in Yorkshire, not excepting the coast, are to be seen in this district.

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* From this latter place the specimen was taken that has been described by J. A. Phillips. *Quart. Journ. Geol. Soc.*, Vol. xxxvii., p. 16.

These sections are best displayed in the grand natural gorge of Newton Dale, through which the York and Whitby Railway runs. The rock is seen throughout a large part of this dale forming a small cliff at the base of the great vertical cliffs of the Kellaways Rock. It has a total thickness of from 12 to 14 feet, and is composed of several bands of different lithological character, as will be seen in the following section :—

Section measured in Newton Dale.

	Ft.	In.
Little shale above.		
Cornbrash limestone, very fossiliferous, passing down into limestone with ferruginous bands, which stand out from the rock in nodular lines, over a thin shaly band full of fossils - - - - - - - - -	4	6
Sandstone, partly decomposed, with plant-like markings -	3	0
Rubbly grey sandstone, more calcareous than the bed above - - - - - - - - -	1	0

The outcrop of the Cornbrash, which is very conspicuous in the cliffs of Newton Dale, may be easily traced on either side of the dale from Levisham Station northwards for about five miles to Crag Stone Rigg, where it bends round to the west, and, although not actually seen at the surface, may be easily traced across the moors as far as Stape by the line of wet ground which it forms at the base of the Kellaways Rock. It is here cut through by the little beck running down Raindale, which severs this part of the outcrop from the main mass, so that the beds to the north of the dale are in reality a large outlier.

From Stape the Cornbrash may be traced by Flamborough Rigg, along the southern side of Sutherland Beck, across the valley of the Seven to Lastingham. The bed is well exposed in the beck just north of the village, and also in the next two becks to the west, namely, Loskey Beck and Hutton Beck. The dip about here being rather steep the beds run up between the several small streams in a series of noses or nabs, which give the Map rather a peculiar appearance.

In crossing the river Dove the bed is not so well seen, but may be followed without much difficulty on the south side of Harland Beck, by Poverty Hill, and above Sleightholmedale Spa, to the Hodge Beck. To the west of this there is a good exposure on the side of a stream on Otterhill Common, but further west there is not much seen of the bed till we reach the River Riccal. Here, although it is not seen *in situ*, there is a good deal of very fossiliferous limestone in the river below Cowhouse Bank, which has probably slipped from the steep ground above.

Beyond this there are no good exposures of the rock, but its outcrop may be easily traced below Roppa Plantation into Bilsdale, although in this direction the beds seem to be getting thinner, and cannot be followed much further with any certainty.

Besides the great outlying mass of this rock on the west side of Newton Dale, there are a few small outliers near Keldy Castle, at Simon Howe, and at Trigger Castle; the last of which is interesting both on account of the good exposure the rock makes,

and also from the fact of its showing the great roll over there is of the strata about here; the beds at this place dipping rapidly to the north, and being only at the same or a lower level than the main mass at Manley Cross; whereas, allowing for the general southerly dip, they should have been at a considerable greater height.

There is also an outlier of the rock on the west side of Bilsdale, the edge of which only comes into this map. This is part of Easterside, the conspicuous hill just east of Hawnby.

The Cornbrash in Newton Dale was several years ago tried as an ironstone, but apparently was not thought to be of much value, as the works which are still to be seen in the bank near Skelton Tower were abandoned without the rock being worked to any extent.

CHAPTER IV.

MIDDLE OOLITE.

The Middle Oolites do not cover any very large extent of area in this map, and occur only as a narrow band along its southern edge. They are a continuation along the strike of the same beds described in the Explanation of Quarter-Sheet 95 N.W., and they also form the northern outcrop of the great range of tabular hills described in the Explanation of Quarter-Sheet 96 S.E., which project into this map in a series of remarkable nabs or headlands facing the north.

The Kellaways Rock.—The Kellaways Rock, which rises immediately above the Cornbrash, may also be well studied in Newton Dale, where it forms the grand natural cliffs on either side of that valley.

The following section measured near the southern end of Huggitt's Scar gives a good idea of its general character:—

		Ft.	In.
	Massive sandstone	30	0
Fossiliferous band.	Sandstone with fossils	3	0
	Soft sandstone full of fossils	1	0
	Soft sandstone decomposed in places	4	0
	Soft, rubbly sandstone	1	6
	Strong sandstone	2	0
	Shaly, flaggy sandstone	18	0
	Massive sandstone	12	0
	Shaly sandstone and sandy shale	10	0
	Bluish shale	8	0
	Total	89	6

This rock, which we mentioned in the explanations of 95 N.W. and S.W., was gradually increasing in thickness from the coast westwards, has in this map attained its greatest thickness, and, including the thin sandstone and shale band above the Scar, has a depth of over 100 feet; this is, perhaps, quite its maximum development, and for the remainder of the map it probably does not average more than from 80 to 100 feet.

In the south-east corner of the map the Kellaways Rock forms the romantic cliffs and the striking moorland terraces on either side of Newton Dale; and, after spreading out in the great outlying mass of Wilden Moor and Wardle Rigg, passes by Flam-

borough Rigg, along the foot of the great tabular escarpment to Lastingham. In this neighbourhood there is a steep dip to the south so that the Kellaways Rock runs up in a series of pointed nabs forming the somewhat remarkable hills known as Askew Rigg, Lastingham Knoll, Spaunton Knoll, and Hutton Knoll, the summits of which are higher than that of the Calcareous Grit escarpment to the south.

West of Farndale the Kellaways Rock skirts round the hill ends by Poverty Hill, Skiplam Moor, and Roppa into Bilsdale. At Coney Birks, in the valley of the Riccal, the rock is very coarse and breaks up into large blocks of grit, one of which was as much as 27 feet in length.

There are two inliers of the Kellaways Rock, one in the Hole of Horcum and the other in the valley below Levisham, but they are neither of any very large extent, and do not call for particular notice. The outliers of the rock are the same as those mentioned in connexion with the Cornbrash, namely, the large mass on the south side of Newton Dale, and the small patches at Simon Howe, Trigger Castle, Keldy Castle, and on the west side of Bilsdale on the flanks of the Easterside hill. The Kellaways Rock has been quarried to some extent on the edge of Newton Dale, near Skelton Tower, where the rock is very compact and forms a good building stone.

The Oxford Clay.—The base of the Oxford Clay in the south-east of the map splits up into sandy layers, and is so intimately connected with the top of the rock below that it is difficult to decide with which some of the beds should be correlated; thus in the neighbourhood of Newton Dale, on either side, there is a thin sandy band which may be traced for a short distance, and which, near Thornsby forms several outliers which have protected the clayey beds below, so that these latter spread over a larger area here than elsewhere. This thin sandstone is also seen at Birk Nab, and might possibly be traced across the map as a thin band, if necessary.

The Oxford Clay rises in a steep bank above the Kellaways Rock, and its outcrop forms a narrow band at the foot of the Calcareous Grit escarpment along the southern edge of the map from Levisham Moor by Newton, Lastingham, Hutton-le-Hole, Brownhill Common, Black Nab, and Roppa Plantation to Bilsdale.

There is also an inlier of this formation in the Hole of Horcum, where it forms the lower part of the steep slopes of that curious hollow.

The best sections of these shales are to be found in the numerous streams which intersect its outcrop, especially in Levisham Beck, Hutton Beck, and Hodge Beck; but as the beds are of no commercial value they have not been opened out artificially.

The Lower Calcareous Grit.—This rock forms the continuation of the grand escarpment of the tabular hills, mentioned in the Explanation of Quarter Sheet 95 N.W., as stretching away from the coast at Scarborough by Hackness and Crosscliff to Saltersgate where the scarp attains an elevation of 950 feet. From this point the beds decline, and entering this map pass by Levisham Moor and Newton to Spaunton, where the summit is not more than about 500 feet above sea level; beyond this the beds again rise and run up in a series of bold headlands between the great intersecting valleys formed by the river Dove, the Hodge Beck, the Riccal, and the Seph. It is to this bed that the Tabular Range chiefly owes its peculiar configuration; these great nabs with their comparatively flat tops have a very characteristic appearance when viewed from some distance.

The Lower Calcareous Grit has a thickness of about 150 feet, it consists principally of yellow calcareous sandstone graduating into shale in the lower part, so that no exact line can be drawn between its base and the top of the Oxford Clay. In the upper part the rock becomes very sandy and contains lines of nodules, similar to those described on the coast, which are well exposed in the bed of the River Seven, about Spaunton and elsewhere. One curious feature connected with the Lower Calcareous Grit in this map are the numerous "griffs" or narrow gullies with vertical sides that have denuded the rock and cut into its lower portion. These are well seen on Levisham Moor; they are often 30 or 40 feet deep and only a few yards wide, reminding one of the cañons of Colorado on a very small scale.

The Passage Beds.—These beds, which formed such a striking feature to the east, appear in this map to be dying out. They are fairly represented about Levisham and Newton, and also at Cropton and Riccal Head west of Spaunton, at all of which places they have been quarried for walling or road-metal; but beyond this they pass into sand or become merged in the great mass of flinty strata at the top of the Lower Calcareous Grit.

As the name implies, these beds present a gradual passage from the sandy beds of the Calcareous Grit to the limestones above; in some cases they are much harder than the beds above or below, which causes them to run out into great tabular features, as at Lockton and Riccal Head.

The Passage Beds crop out entirely along the southern edge of the map, being sometimes in one and sometimes in the other, so that what has been said of them in the Explanation of Quarter-Sheet 96 S.E. applies equally to this Map.

The Lower Limestone.—The Lower Limestone does not make a very large spread in the district, its principal outcrop being on hill tops about Levisham, Lockton, and to the south of Newton; it also just comes into the map at Gillamoor, and beyond the Hodge Beck.

The main mass of the rock is a good oolitic limestone, but towards the base it becomes more silicious, so that the line of junction with the Passage Beds is not easy to trace across country.

The Middle Calcareous Grit.—This bed just comes into the map in the south-east corner, and south of Newton; there is also an outlier of the rock just north of Levisham.

This sandstone does not call for particular notice; there is no section in it in this area, and its outcrop can only be traced by the brown, sandy, silicious fragments lying on the surface which at first sight might be taken for the decomposed remains of the limestone below.

CHAPTER V.

IGNEOUS ROCKS.

The Cleveland Dyke.—The north-eastern portion of the area under discussion is traversed by an igneous rock known as the "Whinstone or Cleveland Dyke." This dyke is a continuation of that described in the explanation of Quarter-Sheet 95 N. W., and enters the eastern edge of this map on Sleights Moor. It is largely quarried about here and sent away by rail; a tramway has been constructed to Goathland Station for this purpose. The rock crosses the Murk Esk at the sharp bend below Spring Wood, where it is again extensively quarried and mined on both banks of the stream, and some interesting facts are brought out.

The dyke most clearly does not lie in a line of fault, and after the molten rock had cooled it seems to have dragged down the beds against its sides, the strata having a sharp dip into it for several yards. The rock at the junction with the sedimentary strata is decidedly finer in grain and contains fewer felspar crystals than in its centre. It is, moreover, almost flaggy at the edges, the long flaggy faces being parallel to the sides of the dyke. The sedimentary strata are altered or calcined by it for a distance of two or three yards from the point of junction. At the outcrop this rock occurs in rounded blocks with tough brown coatings which may be peeled off in concentric layers; the decomposition from which this arises, generally extends right through all the smaller blocks, but there is a decided difference in its amount, due entirely to the beds in which it occurs. Between the beds of oolitic sandstone, which allow the free admission of water, the whinstone is much decomposed; but in the Lias shales, which are almost impervious, it is comparatively unaltered, and is extensively mined in consequence. The rock, where reached in levels at about 500 feet below the surface, occurs in very large blocks about the centre of the dyke, and even the junction faces show little signs of weathering.

For the purposes of this short notice it will not be necessary to enter into a detailed description of the petrological character of this rock.* In a general way it may be described as a bluish-grey augite-andesite, consisting of a ground mass apparently made up of augitic and felsitic matter, with small crystals of felspar and augite. Scattered through this are glassy crystals of triclinic felspar of much larger size, very distinctly visible to

* The Cleveland Dyke will be more fully described in the Memoir on Sheet 104. An exhaustive account of this and other North of England Dykes is given by J. J. H. Teall. *Quart. Journ. Geol. Soc.*, vol. xl., p. 209.

the unaided eye, and which give the rock a distinctive character by which it can be easily recognised.

The outcrop of the Whinstone Dyke is very distinct in the eastern part of this district, being well exposed on Sleights Moor, in the valley of the Murk Esk, and across Lease Rigg to the Esk above Egton Bridge. It is not seen on Limber Hill, but this may be due simply to the covering of drift which here fills the old valley. From Glaisdale Ironworks the rock can be traced almost continuously to West Mire Howe near Fryup End, but west of this is lost under Boulder Clay till it appears again for a few chains at Ainthorp. Between here and Danby Park it may either be absent or hidden by drift, for there are no exposures of solid rock. West of Danby Park the dyke may be traced in a nearly straight line to Commondale Moor where it leaves this map.

CHAPTER VI.

SUPERFICIAL DEPOSITS.

Glacial Beds.

Boulder Clay and Gravel.—The drifts in the North Yorkshire Moors have a curiously partial distribution, for they are entirely confined to the districts connected with the Lias plains, or open to the sea. The Ingleby escarpment appears to have formed an impassable barrier, and though Boulder Clay ascends both the Murk Esk and the Esk, it stops abruptly where the former valley contracts at Hazel Head, and also outside the lateral Dales where these have narrow mouths. No trace of drift is found in any of the Dales, except those connected with the Esk between Grosmont and Castleton, and on the lower Moors in the same district. In the others, and on the adjoining Moors, there is no sign of Drift, and no evidence that it ever existed. The escarpments on the Moors above 800 feet are also perfectly preserved, without any trace of glaciation, so that it is difficult to imagine that these have ever been glaciated, for where the Drift occurs at all the hills are rounded. This is in striking contrast with the Dales of the West Riding, where hill tops 2,300 feet high are beautifully scratched and *moutonnéed*, and are distinctly rounded.

Another interesting fact is that the old drift-filled Esk Valley is both wider and deeper than the present one. Where the valleys coincide the stream flows through a new valley cut in Boulder Clay, without any rock showing. But occasionally the mass of Drift is so great as to turn aside the rivers and force them into new channels. Thus the Esk sometimes leaves its original course and cuts its way through the solid rock, as at East Arnecliffe Wood and Crankly Gill. Here the difference in the size of the valleys is at once apparent; the new valley is a mere steep-sided gorge, in Crankly Gill only 150 yards wide, while the corresponding ancient, and perhaps pre-glacial, valley filled with Drift, is about three quarters of a mile across. The depth of the Boulder Clay below the present bottom of the valley can only be ascertained in two or three places. At Grosmont Mine it is about 45 feet to the rock; at Glaisdale Mines, 53 feet; and at the Tile Works close to Easton Lane in Little Fryup a boring was put down about 60 feet in laminated clay without reaching the Lias. In the last case the surface level is about 30 feet above the Esk. Though it is impossible to say that these sections coincide with the deepest part of the old valley it is probable that they are not far from it. The depth may therefore be calculated at about 50 feet below the present stream.

The great irregularity of the Drift and the absence of good exposures renders it difficult to say much about the succession. As far as can be made out, where the beds are most fully developed, it appears to be:—

Reddish Boulder Clay with few stones;
Sand, Gravel, or Laminated Clay;
Purple Boulder Clay with abundance of foreign rocks, and occasional shell fragments;

—but this succession can scarcely be considered clearly proved, and is partly inferred from a comparison with the coast. No moraines showing local glaciation have yet been found in any of the Dales. The stratigraphical position of the sands with shell fragments seen in the railway cuttings near Lealholm is uncertain; they may either be lenticular masses in the Boulder Clay, or portions of a thick continuous bed.

On the south side of the Esk near Grosmont there is very little Drift, as the river has worked to the south-east of its pre-glacial course, and now often flows over bare Lias. This shifting of the channel is proved by the shaft at the North Mine, the first solid rock being met with nearly 50 feet down. As a consequence there is a very great accumulation of Glacial Deposits on the north-west side of the stream; indeed, we have to ascend as high almost as the Dogger before any rock is seen at all, the whole of the Middle and most of the Upper Lias being completely buried.

Near Egton, at the height of 300 feet at the north-east corner of Farr Carr Wood, there is a clear section of hard, stony, purple Boulder Clay containing undeterminable shell fragments. Close to Egton Church a gravel pit at 550 feet shows:—

	Feet.
Falsebedded sandy gravel and thin brickearths, the stones like those in the Boulder Clay: one small chip of flint. Fragments of *Tellina balthica*, *Cyprina islandica*, *Astarte*? and *Natica*, sp.	9

There is a great quantity of these Glacial Sands and Gravels about Egton Village and on Egton Low Moor, but on the higher ground no fossils were found, as the few openings into it were simply to extract the coarser gravel for road-metal. This gravel stretches along the face of the hill to the old valley near Stonegate, where it joins on to the great mass that covers so large a part of the North Cleveland Hills.

The Esk Dale below Ainthorp contains a very large mass of Drift, which at two places, as mentioned above, has forced the river to seek a new channel. Immediately above Egton Bridge it now flows in a gorge between East Arnecliffe and Limber Hill Woods, but the drift-blocked channel is on the north side of Limber Hill. West of Lealholm there is a similar shifting of the course. It is interesting to notice that in all cases the new course is to the south of the old one, as if the greatest accumulation of Boulder Clay had taken place on the north side of the Dales.

The lower part of the valley of the Murk Esk from Hazel Head northward is filled with Drift, principally Boulder Clay, which

also spreads in a thin sheet over a considerable area of the moors around Julian Park, rising to a height of about 700 feet. Near Julian Park the Drift has forced the Murk Esk to cut a new channel south-east of the old one, and separated from it by a hill of Lower Oolite. At the top of Combs Wood a section shows coarse Boulder Gravel, resting on Boulder Clay. The Boulder Clay is probably thickest where it fills up the course of the Eller Beck, which once flowed almost exactly along the line of the old railway.

The lower portions of Egton Grange and Glaisdale are both filled with drift, and the symmetrical shape of the Dales destroyed by high irregular mounds of Boulder Clay. In Glaisdale, as already noticed, the accumulation has been so great as to force the Beck to cut a new channel. Fryup shows much less drift, there being merely a small quantity at the entrance of the dales.

In the railway cutting about half a mile west of Lealholm Bridge, under or in the Boulder Clay, there is shelly sand containing *Tellina balthica*, *Astarte compressa*, and *Dentalium*. Further west, in a cutting close to Ainthorp Bridge, laminated clay, apparently corresponding with that at the Tile Kiln in Little Fryup, is found; but its relation to the Sand and Boulder Clay can only be inferred from the position in other districts. Above this point the Esk Dale and its branches, Danby Dale, Westerdale, and Basedale are quite free from drift.

West of the watershed the central part of the old valley of the Leven about Kildale is completely filled with gravel containing sand partings, which towards the west passes under an Upper Boulder Clay. This gravel emerges from the Dale in a narrow strip that fringes the lower part of the great escarpment at Battersby Crags. This fringe does not extend beyond Otter Hills, but isolated patches stick up in small hills at intervals over the great flat at the foot of the escarpment. On reaching Midnight Wood, however, another great gravel hill is seen extending up to the foot of the escarpment and attaining a height of about 700 feet. Further west are several other patches of gravel in similar position, all of which are evidently reposing on the Lower Boulder Clay; in fact, there is no Upper Clay in the great quadrangular area at the foot of Burton Head.

Returning eastward across the southern half of the area, we find no trace of Drift, either local or foreign, in any of the Dales which open to the south, or on any of the moors south of the watershed. Bilsdale, Bransdale, Farndale, Rosedale, and Newton Dale, are all quite free from Drift, and the various escarpments in them are perfectly preserved.

Post Glacial Beds.

Peat.—As a whole there is not much peat in this area; what little there is may be divided under two heads, the true hill-peat which grows on the open moors, and the peat of the "Slacks" or upland valleys.

Of this latter kind the best examples are seen about Julian Park, in Lady Bridge and Purse Dike Slacks, and in the large hollow of Randay Mere. At this last place, which has very much the appearance of a small lake-basin, the peat is for a considerable distance both thick and black, and contains many fragments of birch and fine trunks of oak. The present mere is simply a hole made by digging out the peat.

The principal areas of hill-peat occur on the watershed of the country spreading over the grit on Egton High Moor and on the moors above Rosedale and Farndale. On the former moor it covers a considerable area, and in some places cannot be less than 20 feet thick. Most of the other patches of peat occur on the comparatively flat spreads of the Grey Limestone Grit, as, for example, that on the west side of Bransdale and a small patch on the moor near Bilsdale, just above Spout House.

Alluvium.—There are considerable spreads of alluvium in the Esk Valley about Grosmont, at Glaisdale End, and below Danby and Fryup, and also in the Murk Esk as far as the great gorge in Hollins Wood. In fact, the largest areas seem to occur wherever the stream has been dammed up by Boulder Clay and has had to cut itself a new course. There are also alluvial flats in most of the other valleys, but they are not so broad as those of the Esk.

CHAPTER VII.

STRUCTURE AND PHYSICAL GEOGRAPHY.

Physical Structure.—The physical structure of this district is so simple that there is little to be said upon it, and a glance at the geological map is almost sufficient to give a complete idea of its general character. From the strong contrast also of the colours used, together with the hill-shading, the Map resembles a solid model; or it might be likened to a cameo, where the different layers of shell have been removed, the great Lias valleys having cut deep into the substance while the Middle Oolites represent a small portion of the outer shell which has been left at the edge. The great boldness and simplicity of its topographical features render this district one of the best in England for learning the first rudiments of geological mapping; the great terraces of the Kellaways Rock and Calcareous Grit in the neighbourhood of Newton Dale being particularly striking and instructive.

The general dip of the strata is southerly; but an east and west anticlinal which crosses the map nearly along the line of watershed, at the head of the great dales, causes the beds to roll over to the north, and as they approach the Esk to dip rapidly into that valley; north of which they flatten out somewhat, but still dip to the north at a smaller angle. Besides this main axis there are several minor rolls; among others that which has caused the protection of the little outlier of Cornbrash at Trigger Castle. Also some of the marked lines of disturbance mentioned in the Explanation of Quarter-Sheet 95 N.W., just come into this district; for instance, the anticlinal running west from Robin Hood's Bay * crosses the Esk near the edge of this Map and causes the inlier of Lower Lias in that neighbourhood; and the synclinal which forms so striking a feature at Hackness * may be traced eastwards as far as Lockton, where it causes a slight northerly dip for a short distance, but which is nearly dying out here and cannot be followed much further.

Physical Geography.—The physical geology of this area is remarkable for the boldness of its character, and for the great beauty of the scenery which it gives rise to. It forms three distinct types of country. The Lower Oolites, which cover the greater part of the area, form wide-spreading moorlands, which run up to the watershed across the centre of the map and constitute the most elevated ground int his part of Yorkshire.

* Memoirs of the Geological Survey. Explanation of Quarter-Sheet 95 N.W., p. 54.

These are intersected by deep valleys with steep and often precipitous sides, which have been cut through into the Lias; causing sheltered dales that have been brought into cultivation and are dotted with habitations. With the exception of the low ground in the north-west corner, and along the valley of the Esk, all these deep valleys are free from drift; and consequently the features formed by the different beds are sharp and distinct. The sandstones of the Lower Oolite form a steep and often craggy acclivity around the crests of the valleys.

Lastly, the Tabular Hills, along the southern edge of the district, form a third area. Although the great headlands projecting into this map are also generally moorland, these uplands soon fall to the south, and where the limestones supervene the land is enclosed and brought into cultivation, the country there being far more populous than the wild district to the north.

A word may be said on the general denudation of the country. It will be observed that nearly all the valleys run across the strike or with the dip of the strata; showing that within this area at least the inclination of the beds has given the initial direction to the streams. Thus those in the south half of the map, lying as they do south of the anticlinal axis flow south to the Derwent, while those in the north half, being north of this line, flow north into the Esk, which itself runs east along a line that seems to correspond to a certain extent with a general flattening of the beds. All the valleys running south cross the range of the Tabular Hills; and it is evident that the courses of these streams must have been determined before the formation of this great escarpment. Two of these valleys, namely, Newton Dale on the east side of the map and Bilsdale on the west, have both cut their way back to join the valleys on the north side. In the former of these cases the water which issues from Fen Bogs at the summit of the dale flows in both directions, and it would take but a small artificial obstruction to divert the upper waters of the Eller Beck to the south down Newton Dale. Bilsdale ends on the north in two narrow passes, one on each side of Hasty Bank, the ground to the north being at a considerably lower level; and it would appear as if these valleys had originally extended further north, but have been cut off by the recession southwards of the Oolitic escarpment.

Faults.—On the whole the beds shown in this Map are very little disturbed, and there are no faults of any magnitude. In the bank, to the north of Castleton, there are two small breaks which, together, throw down the Grey Limestone about 50 feet on the east. West of the village there are two small trough-faults slightly depressing the beds between them in the neighbourhood of the junction of the Esk with the stream from Basedale.

On the east side of Bilsdale a small fault having a downthrow to the east slightly shifts the base of the Oolites above Bracken Hill, and apparently cuts out the base of the Grey Limestone for

some distance, but the outcrop on the moors about here is rather obscure; on the east side of this fault there is a small spur of it having a throw in the opposite direction.

In the vicinity of Lastingham there are three faults all having a small downthrow to the west. The first of these, which is just east of Farndale, causes a slight shift in the base of the Kellaways Rock, which may displace the beds rather more than is shown in the map; as it is possible the outcrop of the Cornbrash, on the east side of the fault, turns in more towards Barmers Lodge, there being a line of wet ground crossing the road here which looks like the base of the Kellaways Rock, but no Cornbrash was seen.

East of Hutton-le-Hole there is a small fault which breaks the Calcareous Grit escarpment, and, depressing the beds on its west side, causes a great spread of the Passage Beds to outcrop here forming the fine tabular feature at Riccal Head. This fault, which seems to die out before it reaches the Lower Oolites, becomes more important to the south and is the same as that mentioned at Sinnington in the next map as having a throw of about 100 feet.*

The last fault, which is just east of the Seven, causes a good deal of local disturbance of the rocks, and high dips are seen in the river, but it does not appear really to shift the beds much.

* Memoirs of the Geological Survey. Explanation of Quarter-Sheet, 96 S.E., p. 33.

APPENDIX.

LIST of the more IMPORTANT WORKS referring to the GEOLOGY of this part of YORKSHIRE. A fuller List will appear in the General Memoir on the "YORKSHIRE OOLITES."

1821.

WINCH, N. J. Observations of the Eastern Part of Yorkshire. *Trans. Geol. Soc.*, vol. v., p. 545.

1853.

PHILLIPS, PROF. J. A Map of the Principal Features of the Geology of Yorkshire. (Scale 5 miles to an inch). *York.* Ed. 2 in 1862.

1857.

CROWDER, W. An attempt to determine the Average Composition of the Rosedale, Whitby, and Cleveland Ironstones. *Edin. New Phil. Journ.*, ser. 2, vol. v., p. 35.

MARLEY, J. Cleveland Ironstone. *Trans. N. of Eng., Inst. Eng.*, vol. v., p. 165, (Discussion, vol. vi., pp. 7, 187; 1858.)

1858.

BEWICK, J. Remarks on the Ore and Ironstone of Rosedale Abbey. *Trans. N. of Eng., Inst. Eng.*, vol. vi., pp. 15, 187.

PHILLIPS, J. On some Comparative Sections in the Oolitic and Ironstone Series of Yorkshire. *Quart. Journ., Geol. Soc.*, vol. xiv., p. 84.

1859.

WOOD, N. On the Deposit of Magnetic Ironstone in Rosedale. *Trans. N. of Eng. Inst. Eng.*, vol. vii., p. 83.

1861.

BEWICK, J. Geological Treatise on the District of Cleveland, in North Yorkshire, its Ferruginous Deposits, Lias, and Oolites; with some observations on Ironstone Mining. 8vo. *London.*

1864.

PERCY, DR. J. Metallurgy [vol. ii.]. Iron and Steel. (Table of Analyses of British Iron Ores, Yorkshire, pp. 211, 221–223). 8vo. *London.*

1870.

MARLEY, J. On the Magnetic Ironstone of Rosedale Abbey. *Trans. N. of Eng., Inst. Eng.*, vol. xix, 193.

1874.

HUDLESTON, W. H. The Yorkshire Oolites. Part I. *Proc. Geol. Assoc.*, vol. iii., No. 7, p. 283.

1875.

PHILLIPS, PROF. J. Illustrations of the Geology of Yorkshire. Part I., Ed. 3. 4to. *London.*

1876.

HUDLESTON, W. H. The Yorkshire Oolites. Part II. *Proc. Geol. Assoc.*, vol. iv., No. 6, p. 353.

TATE, R. and BLAKE, J. F. The Yorkshire Lias. 8vo. *London.*

1877.

BARROW, G. On a New Marine Bed in the Lower Oolites of East Yorkshire. *Geol. Mag.*, dec. II., vol. iv., p. 552.

BLAKE, J. F. and HUDLESTON, W. H. The Corallian Rocks of England. *Quart. Journ., Geol. Soc.*, vol. xxxiii., p. 260.

1878.

HUDLESTON, W. H. The Yorkshire Oolites. Part II., sec. 2. *Proc. Geol. Assoc.*, vol. v., No. 7, p. 378.

1881.

PHILLIPS, J. A. On the Constitution and History of Grits and Sandstones. *Quart. Journ. Geol. Soc.*, vol. xxxvii., p. 6.

1884.

TEALL, J. J. H. Petrological Notes on some North-of-England Dykes. *Quart. Journ. Geol. Soc.*, vol. xl., p. 209.

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